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EXPERIENCES IN THE TREATMENT OF THE ALLERGIC NASAL POLYP BY THE INTRAPOLYP INJECTION OF PREDNISOLONE T B A

DAVID MYERS, M D ,[*,**,†,‡]
Philadelphia, Pa

Historically, the presence of the nasal polyp has been known for centuries It is stated that Hippocrates described nasal polypi, gave theories as to their origin, and described techniques for their removal Many theories of polyp formation have been described from these early days

The pioneer and monumental works of Drs Kern and Schenck[1,2,3,4,5] helped to establish, without doubt, the allergic origin of the nasal polyp Other pioneers in the description of the allergic origin of the nasal polyp were Hansel,[6,7] Weille,[8] Coates and Ersner[9]

Histopathologic study indicated the intense infiltration and edema of the tunica propria The most recent advances have imparted further information as to the importance of connective tissue and the so-called ground substance The diseases producing the changes in the ground substance have been called by Klemperer[10]—the collagen diseases Semenov[11] believes that the nasal polyp is a manifestation of the collagen

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[*] Read at the Sixth International Congress of Otolaryngology Washington D C May 6 1957

[**] From the Department of Otorhinology Temple University Medical Center

[†] The prednisolone® T B A was supplied by Merck Sharp and Dohme—Brand Hydeltra T B A.

[‡] The study on the pathology of the polyp was carried out by Dr Elizabeth Holmes of the Department of Pathology Temple University Medical Center under a grant supplied by the Sharp & Dohme Co Further publications of these studies are to follow

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disease The pathologic changes in almost every case center in the mesenchymal substance of the tunica propria Rawlin[12] has suggested that the nasal polyp resembles embryonal, mesenchymal tissue This recent experimental and histologic study, which is too extensive to mention in this short presentation, establishes that the nasal polyp is allergic in origin, and that the pathologic change is in the subepithelial tissue or connective stroma This is due to some abnormality of the connective tissue stroma and of the ground substances The polyp is not a true tumor, but is a swollen mass of thickened connective tissue Proof exists that the hormonal effect of ACTH and Cortisone affects more directly the ground substance of the connective tissue

Bordley,[13 14 15] and his associates at the Johns Hopkins Hospital, were among the first to notice the amazing changes that occurred in the mucosa of the upper respiratory tract They noted the fact that nasal polypi completely or almost completely disappeared Other reports soon followed Thorn et al [16] noted shrinkage, but not complete regression of polypoid and antral mucous membrane, following the use of ACTH in allergic states As occurs after the discovery or availability of any new drug or substance, it is subjected to a general trial by every field As the result of the experiences in other fields, many uses of ACTH and Cortisone have been started in otolaryngology

Ashley[17] treated six patients with chronic allergic rhinitis and polypoid nasal mucosa, and found a striking change in the tissues of the nose and pharynx Semenov[11] treated patients with polypoid rhinitis, with topical Cortisone and by injection of Cortisone into the septal mucosa and polyp Davison[18] suggested the treatment of hyperplastic sinusitis of allergic origin with bacteriocidal doses of penicillin and Cortisone orally Dill and Bolstad[10] used Cortisone locally in two reports Wall and Shure[20] used the injection of Cortisone submucosally in the inferior turbinate Randolph and Rollins[21] used ACTH locally in clinical ragweed hay fever and asthma

Stewart and Kawa[22] reported experiences with Cortisone and ACTH in the treatment of allergic rhinitis Smith[23] reported on the local use of hydrocortone acetate in the nose Other reports on the intranasal use of medication containing Cortisone were made by Seidman and Schaffer,[24] Schwarz,[25] Silcox[26] and Evans[27] Hotchkiss[28] reported on the oral use of prednisolone in nasal polyposis Owen[29] reported on the treatment of nasal polyposis by the injection of hydrocortisone directly into the nasal polyp

The purpose of this paper is to report our own experiences with the treatment of nasal polypi by the intrapolyp injection of corticoid substances This has extended over a period of six years This included the injection of ACTH, Cortisone, hydrocortisone, hydrocortisone T B A , and during the past one and one-half years, with Prednisolone T B A (in the form of suspension Hydeltra® T B A , supplied by Sharp & Dohme, Division of Merck & Company

We first used ACTH and Cortisone approximately six years ago, after reading the reports of the first ACTH conference and the experience of Bordley, Hench, and others previously quoted Our first experience was with ACTH The first patient was a man, age 60 He was a baker, and gave a history of allergy of many years' duration He had already undergone numerous bilateral polypectomies, and several radical sinus procedures After several intrapolyp injections of ACTH, the polypi disappeared completely, and to date have not recurred We then treated three or four other patients similarly and found a regression of the polypi

Cortisone then became available, and it appeared to us that since ACTH acted on the adrenal glands to produce Cortisone, that using Cortisone itself locally, might produce a more beneficial, and a quicker result It is noted that when using the intrapolyp injection of Cortisone solution, poor results were obtained After treating eight patients in this manner, it appeared that this treatment was not beneficial Soon after, in December, 1951, the experiences of Hollander[30] and his co-workers, using intra-articular injections of Hydrocortisone (or Compound F) were reported This report indicated that this was a safe method of injection and treatment, and resulted in local relief of symptoms It was then that we began to use this particular drug in the intra-polyp injection therapy It was found that there was a prompt regression of the nasal polyp with the injection of Hydrocortisone solution into the polyp In this time, a total of 38 patients have been treated by the intrapolyp injection of Hydrocortisone solution T B A , with a total of 228 injections At no time was there a local or systemic reaction following this injection

In May, 1956, we began to use Prednisolone T B A in the form of suspension Hydeltra®T B A , supplied by Sharp & Dohme Company This is Prednisolone tertiary-butylactate (Merck), a very slightly soluble ester of Prednisolone, and it is capable of producing longer local anti-inflammatory action This report will concern itself with our experiences with Prednisolone T B A , since others mentioned above have reported on the use of the other compounds

Since we started using this compound, we have treated 30 patients with nasal polyposis by the injection of Hydeltra® T B A The patients were given over 150 intranasal injections, and there were no untoward reactions, either locally or systemically

The following is a description of the technique Approximately 2 cc of solution are used at each treatment One cubic centimeter is injected into the polypi of each nasal chamber Each cubic centimeter contains 20 mgm of Prednisolone tertiary butyl acetate The material is injected into the polyp in the following manner The nasal membrane is sprayed with a solution of one per cent ephedrine sulfate This renders the nasal polypi relatively more accessible The actual injection into the polyp is done without local anesthesia, since the polyp or polypoid tissue seems to be insensitive to the entrance of the needle A 25-gauge, 3½-inch needle is used The needle is inserted into the body of the polyp, and a few drops of the Prednisolone are injected, until the back pressure on the piston of the syringe is felt This is repeated from polyp to polyp until 1 0 cc is given in each nasal chamber The total dose of Hydeltra® T B A is about 30 to 40 mgm at each treatment, depending upon the amount of solution the polyp will accept This treatment is repeated each five to seven days, see Figs 1 and 1-A

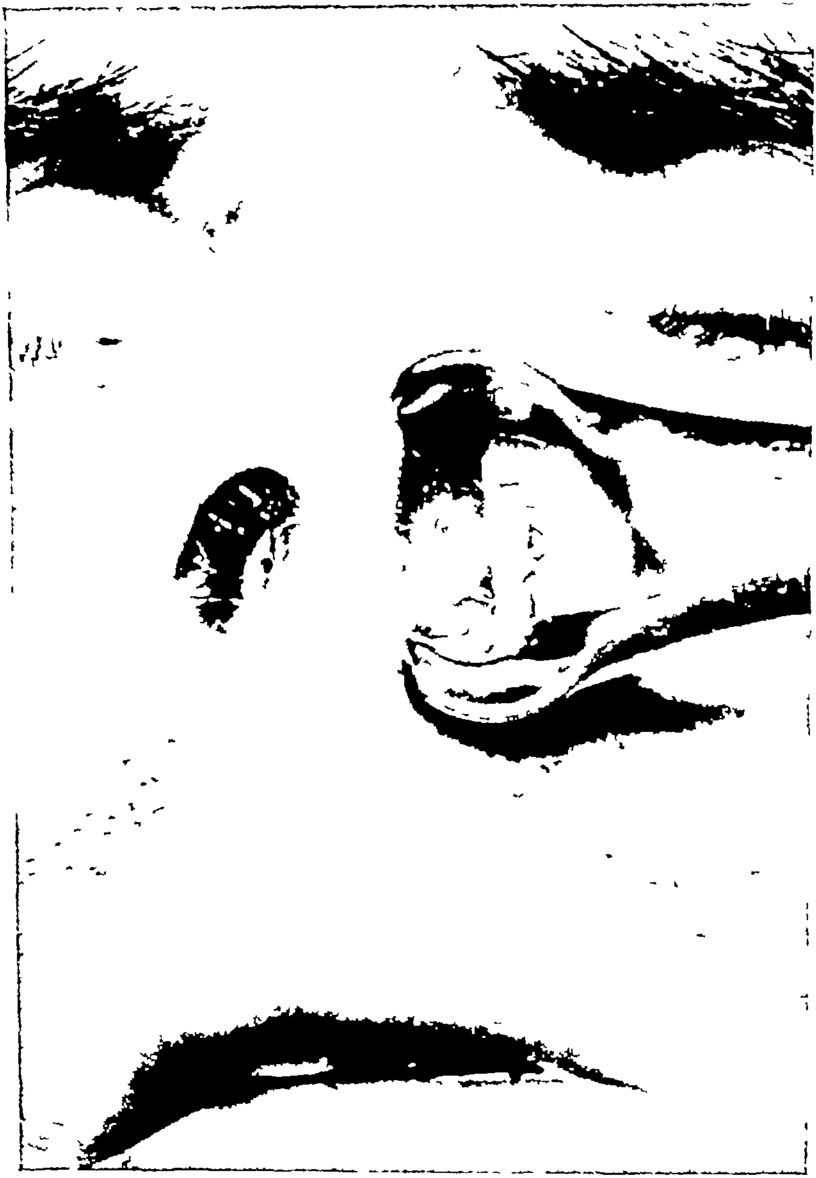


Fig 1. A typical nasal poyp

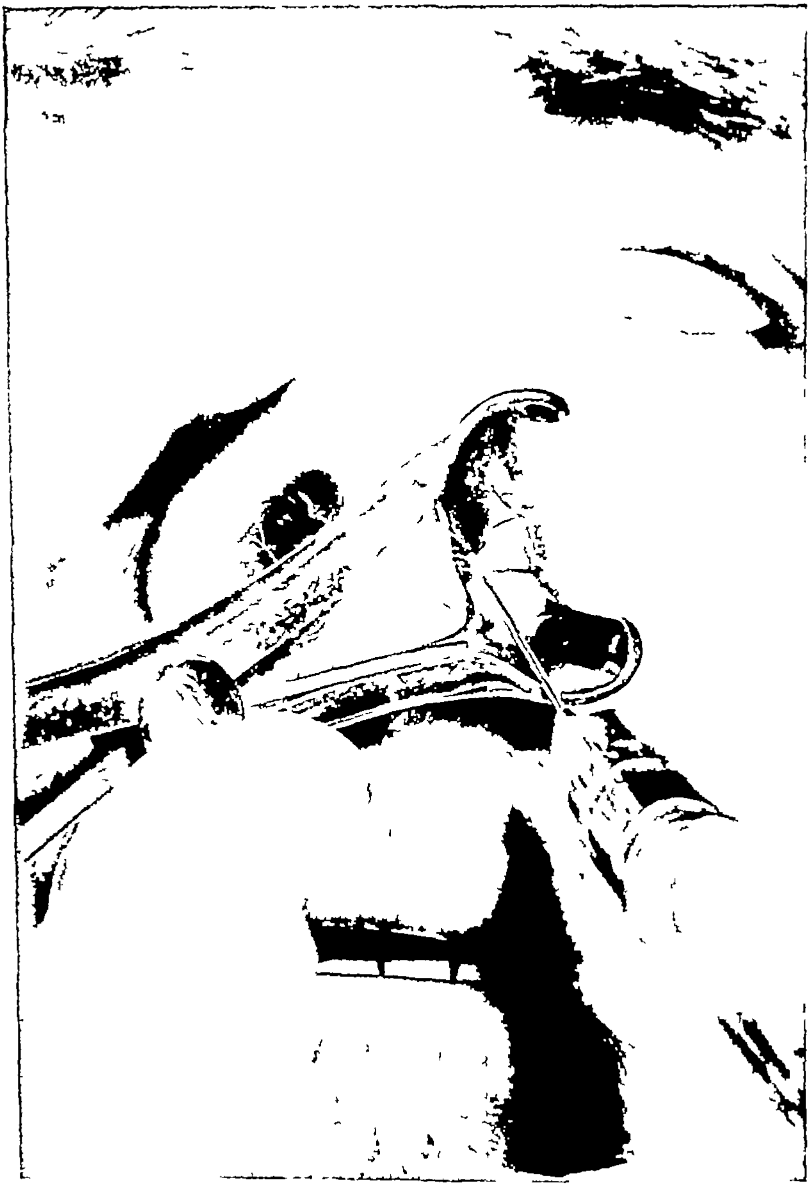


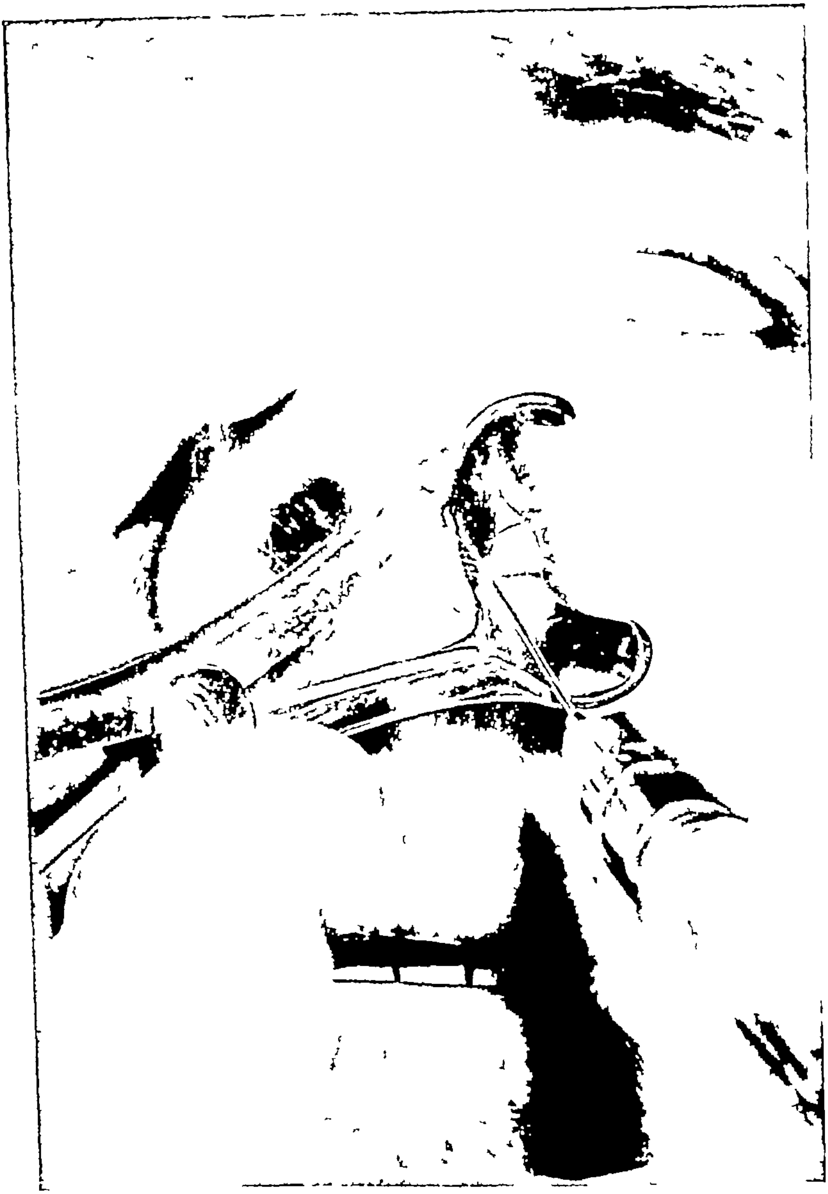
Fig 1-A Technique of injection of the nasal polypi

Following the first or second injection, the nasal mucosa becomes a pale, bluish white The edema subsides The polyp will often regress more than half during this time Sometimes after three or four injections, the polyps are practically gone The patients state that they had not only relief of breathing, but many of them felt that they had regained their sense of smell During the course of this investigation, biopsies were taken prior to the injection, and a study of the polyp was made On several occasions, a biopsy was taken immediately after the Hydeltra® T B A was introduced into the polyp, but it was found that microscopically no evidence of the presence of the medication could be seen As the polyps regressed in size, further biopsies were taken It was noted that as long as there was any polyp tissue present, despite its decreased size, the histologic appearance varied little from the full sized polyp

Experiences from pathologic studies—When this study was started, and sections of polyp tissue were taken, it was hoped that histologic study would reveal noteworthy changes It was noted, however, that despite the regression of the size of the polyp, as long as any polypoid tissue remained, the histologic picture was identical In collagen diseases, however, microscopic changes are difficult to note It is probably necessary to view the tissue with the electron microscope to note changes in the fibrillary structure More important is the probability that the changes that occur, which result in the production of the polyp, are in the ground substance of the tunica propria, and are chemical changes rather than histologic changes

The following are excerpts from the histopathologic reports of nasal polypi of several patients under treatment with the intrapolyp injection of Prednisolone

Case 1 Sections, labeled from right and left nasal chambers, show a similar picture The sections show polypoid tissue partially covered by pseudostratified columnar epithelium The stroma is extremely loose and edematous, and is liberally sprinkled by leukocytes, which are predominantly plasma cells and eosinophils



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There are areas of increased capillarity and of catarrhal activity of contained mucus glands The former feature is present beneath the surface mucosa, thus suggesting granulation tissue formation The edema and the eosinophilic response would support the clinic impression that these polyps are on an allergic basis

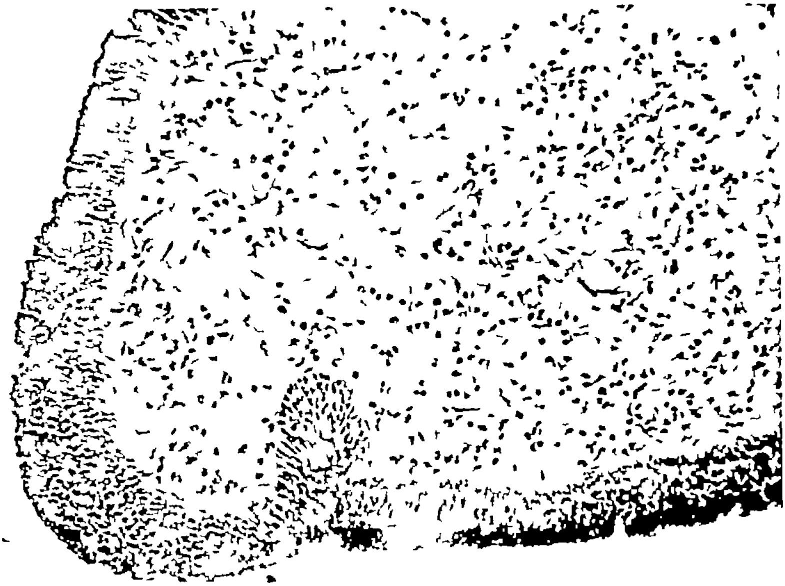

Fig 2 Nasal polyp after one injection of Prednisolone T B A

After an injection of Prednisolone, the polyp was reduced to approximately half its size on gross inspection A biopsy was taken which revealed the following, see Fig 2 The polypoid structure shows an edematous stroma which contains focal collections and a diffuse of lymphocytes and eosinophils The surface epithelium is intact and of the tall columnar, occasionally pseudostratified type

Case 2 A nasal polyp after five injections of Prednisolone T B A The nasal polyp described here was very small On gross inspection of the nose it had almost disappeared compared to its appearance when the injection treatment was started It was noted histologically that the essential structure remains unchanged, with the exception of the regression of the edema, see Fig 3

The polypoid fragments show considerable edema, and mild to moderate leukocytic infiltration of the stroma The The latter response is in the form of small groups of cells in some areas, and in other places the cells have a scattered, sprinkled appearance These cells are of all varieties with the plasmocyte and the eosinophile predominating There is one small area of recent hemorrhage, surrounded by fibroblasts and by pigment-laden cells, but this does not have the appearance of venous thrombosis The surface epithelium is thickened but of the pseudostratified respiratory tract type

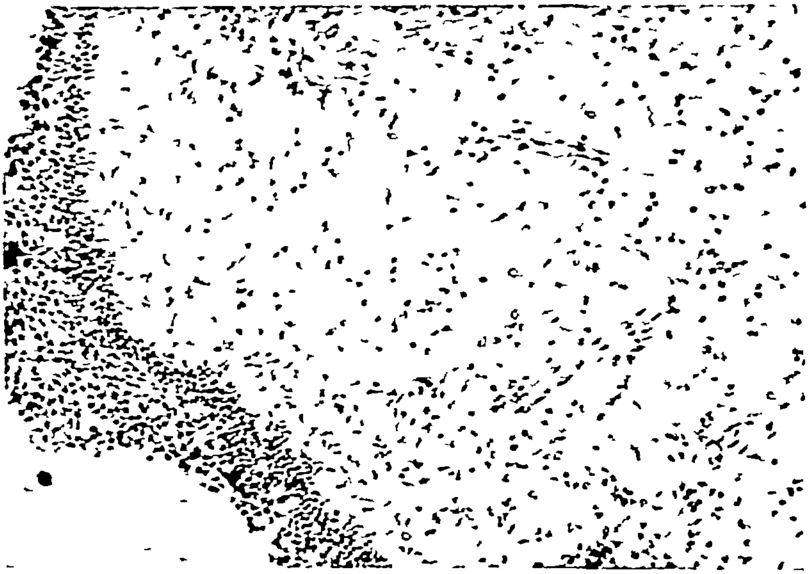

Fig 3 Nasal polyp after five injections of Prednisolone

Other observers have similar experience on histologic study Rappaport, et al ,[28] state as follows "The mucosa of 46 patients with ragweed pollenosis were studied before and after ACTH therapy The mucosa obtained at the end of four days of treatment with ACTH, when compared with that removed before treatment, showed consistently the following changes *1* a general increase in stainability of the glycoprotein ground substance, *2* an increase in the cement substance between the epithelial cells of the mucosa, *3* an increase in the staining density and in the width of the submucous and of the perivascular "basement membrane", *4* an increase in the number the thickness and the stainability of the fibers in the ground substance, *5* an increase in the number and the size of red-staining granules in the cytoplasm of stellate, oval and round cells present in the submucosa These cells are believed to be undifferentiated fibroblasts (mesenchymal cells), and the granules to be glycoprotein in composition It would appear from these results that during the allergic reaction the glycoproteins of the ground substances and the basement membranes are broken down (depolymerized) to smaller units with a proportionate loss of stainability The effect of Corticotropin is to arrest the process of depolymerization Glycoproteins are restored to a normal state with a resulting increase in stainability

In several patients the polyp reached a certain point in its regression, and then did not become smaller after further injections In those it was thought that possibly some fibrotic change in the mucous membrane had occurred, and that the remnants of the polyp could be removed surgically Some polypi did not reduce in size following the injection, and it was thought that possibly some etiologic factor other than allergy was involved, and that treatment was discontinued In some patients there was a recurrence after several weeks or several months This often followed an upper respiratory infection, or after contact with a known allergen, or some psychosomatic upset In these patients, the injections were repeated, and the same effect was obtained The injections may be repeated numerous times with the same beneficial results, and apparently without reaction or ill effects

From my experiences with injections of Prednisolone T B A , I found that it was a safe method, and that no local or general reactions have occurred A regression of the polypi occurs promptly, and the patient has considerable relief There is no pain or bleeding This method may be used to give temporary relief while allergic control and management is obtained It may be used in patients who are unsuited for surgery because of various physical reasons It may be used during acute allergic exacerbations while awaiting the benefit of allergy study and desensitization Kern and Schenck[1] long ago recommended that surgical procedures be avoided during acute allergic exacerbations, such as pollen season, or during acute asthmatic exacerbations This method will give the patient considerable relief while in this acute stage Many times when the maximum benefit of injection therapy is reached with Prednisolone T B A, the residual polyp tissue may be removed with very little trauma to the nasal mucosa or sinus mucosa In the event of recurrence, it is a simple matter to repeat the injections and see the same beneficial results Hollander[30] found that repeated injections in the arthritic are equally effective and may maintain remission of symptoms for long periods He also found an absence of systemic effects and adverse reactions from this local method of utilizing hydrocortisone Cessation of injections has not been followed by exacerbations of the local inflammation, but only by relapse to pre-treatment status In severe allergic states, the remnants of any nasal mucous membrane, however small, can be the site of polyp or polypoid formation, therefore, even if the polyp recurs after the Hydeltra® T B A, then the further injection may result in its disappearance, or surgical removal can be carried out

Many observers have shown that despite the degree of radical surgical treatment there will be recurrence of polypoid rhinitis, polypoid sinusitis, or bronchial asthma, unless some degree of allergic control can be obtained Kern and Schenck,[1] Tuft and Blumstein,[31] Pepys and Duveen,[32] and Chait[33] have reported regression of nasal polypi after proper and continued allergic management and desensitization therapy The lesson to be gained is that the nasal polyp and the lining membrane of the paranasal sinuses are capable of return or regression to normal

Some typical case reports are as follows

Case 1 The patient age 47 male was first seen on May 10 1956 His history revealed nasal congestion sneezing rhinorrhea and headache Twelve years ago an intranasal polypectomy had been performed and again three years ago The present examination revealed multiple nasal polypi in each nasal chamber The polypi were injected with Predisolone T B A Three treatments were given at weekly intervals At each examination it was noted the polypi were smaller one week after the last treatment they were no longer visible The patient has remained comfortable since this treatment

Case 2 This patient a female was first seen in October 1946 The patient stated that during the past year she had developed rhinorrhea cough asthma and sneezing She lost her sense of smell and taste In November 1945 a polyp had been removed from each nasal chamber At this examination the nasal mucosa was pale and boggy The right middle turbinate was hypertrophied Many large polypi were present in the right middle meatus On transillumination both antra were cloudy Under local anesthesia the nasal polypi were removed The patient was next seen in December 1948 at which time she stated the polypi had recurred within a short time and they were again removed by another rhinologist The patient then had a severe attack of asthma and was hospitalized successively at four different hospitals by as many physicians The nasal examination now revealed multiple nasal polypi bilaterally, which completely occluded each nasal chamber It was suggested that complete allergic care and management was indicated Sinus X rays were made December 6 1948 at Temple University Hospital where it was shown that both maxillary sinuses were completely opaque Despite continued desensitization therapy medical care and management the patient s asthma continued and her polypi remained A bilateral transantral ethmoidectomy was done in February 1949 In January 1950 polypi were again removed In January 1951 when she was again seen ACTH was available and it was then that the injection of the nasal polypi with ACTH was done The patient returned for a series of injections into each nasal chamber The polypi became smaller after each injection and she began to feel more comfortable Cortisone then became available and on April 28 May 15 and May 28 1951 Cortisone was injected into the polypi This did not reduce the size of the polypi Because of the poor results with Cortisone ACTH was again injected and this time after several injections, the polypi disappeared On February 16 1953 both nasal chambers were free of polypi The patient returned again in January 1956 polpi were again present and this time the Prednisolone T B A was used After four treatments both nasal chambers were clear This case illustrates that surgery alone cannot control nasal polyposis The cure is bound up in the general allergic state and until this can be completely managed polypi will recur The intrapolyp injection is a mode of management and helps avoid repeated surgery

Case 3 This patient male age 53 was first seen with a chief complaint of nasal congestion rhinorrhea and sneezing He had had four previous polypectomies The present study revealed recurrence of polypi with complete closure of both nares Prednisolone T B A was injected into the polypi The injections were repeated at weekly intervals and it took seven treatments to free the nose of polypi There were no untoward local or systemic reactions When last seen the nose was free of polypi

Case 4 A female patient age 40 was seen on May 18 1956 with a history of asthma for the past four years Four previous operations for the removal of nasal polypi had been done and she still complained of nasal congestions and discharge Examination revealed recurrent bilateral polyposis and allergic rhinitis The polypi were injected with Hydeltra T.B.A on eight occasions These injections were made at weekly intervals After the fifth injection the polyps were practically gone except for small residual polypoid areas On the left side a dense fibrous sac the residual of one polyp, remained This sac was removed with a nasal snare The patient was re-examined in two months at which time the nose was still clear The patient was referred for general allergic study and management At present she is receiving desensitization therapy

Case 5 R F age 42, was first seen in December, 1946 at which time a bilateral polypectomy was performed He was well then until December 1955, at which time he was admitted to the Temple University Medical Center with asthma and hypertension, and anginal symptoms Both nasal chambers were completely filled with nasal polypi These nasal polypi projected from the nares (see Fig 1) Daily injections of Prednisolone Hydeltra T B A were given for a five day period, following which the complete regression of the nasal polypi was noted

The injection technique helps with the management of the allergic patient as illustrated by the following Mrs R P had allergic rhinitis for many years Despite constant allergic care and management by an allergist, she had frequent recurrences of nasal polypi The patient can tell when her nose is obstructed and reports for treatment on her own, at which time the nasal polypi are injected The swelling and polypi are reduced, and the patient feels better for varying lengths of time, then she is again seen In this way, we avoid multiple surgical excisions and keep our patient comfortable

SUMMARY OF CASES TREATED

	Patients	Injections
ACTH	5	28
Cortone	5	40
Cortone F (Hydrocortisone T B A.)	38	228
Prednisolone (Hydeltra T B A)	30	220

Case 6 Mrs R Z an elderly female age 70, had allergic rhinitis for many years She had numerous polypectomies and four years ago had a bilateral Caldwell Luc and transantral ethmoidectomy Despite this nasal polypi continued to recur There is a definite seasonal cycle When the patient has nasal congestion and obstruction she returns for injections with subsequent relief In three years of observation she has had numerous injections with relief for varying periods Polypi continue to recur, but we have avoided surgical excision

Control studies have been done at varying times, injecting the polypi with distilled water, hyaluronidase, and antihistaminic substances No results were obtained in our experiences This was done only once or twice in the patients selected, because it was felt that it was unfair to withhold relief for a longer trial

Since the advent of the Prednisolone T B A we have used this exclusively There have been no systemic reactions The polypi are injected, and on the return visit, considerable regression is usually noted Sometimes, the polypi disappear completely after the first injection At other times, the remnant of the polyp is seen to be covered with a thick, plastic exudate, and when this is removed by the use of suction, the remnant of the polyp can be aspirated and removed in this way There were very few allergic polypi that did not decrease in size after the injection Most patients were relieved by the treatment The number of doses varies Some patients have complete regression to a normal state, others only very temporary relief The amount of relief varies with the allergic problem and the allergic reaction that caused the flare-up and recurrence In most cases, the regression of the polypi can be hastened by the use of corticosteroid substances in conjunction with the injection therapy In some patients the decrease in the size of the polyp stops at a certain point and no further improvement can be obtained In these patients, the conventional snare and punch technique is used for the further removal Since we have been using this treatment we have done very few surgical polypectomies This is reserved for the occasional patient who has residual fibrotic tissue after the injections are completed Most patients who have polyps have already experienced a great deal of surgery, and are happy to have a try at injection therapy even if it means repeated visits

This treatment would indicate that polypi can be reduced without surgery, and that we can perform a minimal of intranasal surgery Sometimes on the first visit, if a patient is very uncomfortable, the larger polypi can be removed by the snare, and this gives quicker relief Then the remaining polypi are treated by injection therapy This is mentioned to indicate that the steroid injection therapy has a place in our therapy, and its use can be varied by the rhinologist's judgment and experience with the method In the beginning, the injection was used alone to study its benefit At times, a combination of the snare, injection and oral corticosteroid therapy give quicker and more permanent relief In my present experience and thinking, radical attack on the ethmoidal labyrinth will be rarely indicated

DISCUSSION AND CONCLUSION

The advent of increased knowledge of the tunica propria, the supporting fibrillar network, and the collagen ground substance, has given an impetus to the study of many types of allergic and inflammatory reactions The mesenchymal tissue, long neglected, has now assumed an important place These advances have been possible because of the electron microscope, advanced biochemical research, and the endocrinologic research, resulting in the availability of the many corticosteroid substances The use of these substances has enabled us to cause the regression of allergic reactions Hench[34] stated "Aside from epinephrine, these are the first hormonal agents with marked anti-allergic properties" The treatment of nasal polypi by the use of Prednisolone T B A is described Good results, with relief of symptoms, have been obtained in most cases This occurred without local or systemic reaction It permits the full utilization of the anti-inflammatory activity of corticosteroids at the tissue level without producing systemic effects In the event of recurrence, the injections can be repeated many times If there is no response to this therapy, then surgery can be instituted The important lesson is not a new treatment for polyposis, but that nasal mucous membrane, having undergone polypoid change, is capable of regression to normal, or near normal, and should be respected rather than exenterated

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3701 N Broad St

PIETRO CALICETI AWARD

Dr Samuel Rosen, of New York City, has been honored with the first Pietro Caliceti Award for his outstanding work in stapes mobilization He is consulting otolaryngologist at Mount Sinai Hospital

The Award—a medal, diploma and $1600, was made to Dr Rosen in Bologna, Italy, December 13, 1957 It was established in memory of Professor Caliceti, director of the University of Bologna, who died in 1951 It is to be given on an international basis every four years for the most significant and published work in otorhinolaryngology

STAPES MOBILIZATION

Lasting Results at One and Two Years[*][†]

YRJO MEURMAN, M D ,
and
OTTO H MEURMAN, M D ,
Helsinki, Finland

TECHNIQUE

In 1955 we published the results obtained in the first 63 cases operated upon by stapes mobilization in the Otolaryngological Clinic of the University of Helsinki The operations were performed by the original Rosen technique, though in most cases with the aid of a binocular Zeiss operating microscope In 25 cases the improvement in hearing was good, in 12, slight, and in 26 no result was obtained Very many of the failures were due to crural fracture and persisting fixation of the stapes footplate Our technique has since been modified to obtain better visualization of the oval window and to facilitate mobilization

In the spring of 1955, at the meeting of the German Otolaryngological Society, Dr Y Meurman presented results obtained with his method the atticus is opened through an endaural incision, and the corpora of the ossicles exposed, this is followed by removal of the bridge which results in good visual exposure of the oval window region If the stapes is solidly fixed, the footplate itself is mobilized by breaking the bony connections with thin lancet-pointed knives Opening of the attic, however, is not required for proper visualization of the oval window, therefore, we later adopted the following technique an ordinary circular endaural incision is made near the orifice of the external meatus, and from the uppermost point of this incision, another incision is carried for

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This manuscript received in The Laryngoscope Office and accepted for publication May 13 1957

some distance upward between the tragus and the helix The skin of the upper and posterior meatal wall is dissected from the bone down to the drum margin, and the posterior margin of the drum is then freed from its sulcus In the area where the chorda tympani leaves the facial nerve, some of the bony margin of the tympanum is removed, using a burr so as to allow proper visual exposure of the stapedial tendon, the facial canal, the crura, and most important, the footplate itself Several variations have been used for the actual mobilization Initially we often tried, after the foregoing approach, to mobilize the footplate by applying pressure on the neck of the stapes in the direction of the stapes tendon, or by applying pressure to the end of the long process of the incus in an attempt to push the stapes inward During 1956 we began to use more and more direct mobilization of the footplate, either by breaking the bony connections between the footplate and the window margins with a lancet knife, or with a needle probe Ordinarily it has sufficed to mobilize the footplate at the anterior periphery of its attachment to the anterior crus and at the posterior periphery of its attachment to the posterior crus, but occasionally it has been necessary to break connections also at the superior and inferior margins of the footplate As far as possible we avoid fracturing the crura

TABLE I

CASES OF STAPES MOBILIZATION (SHAMBAUGH'S CATEGORIES)

	A	B	C	Total
1954	64	29	8	101
1955	89	34	13	136
1956	94	46	2	142
Total	247	109	23	379

MATERIAL AND INITIAL RESULTS

In Table I the cases are classified by Shambaugh's criteria and year of operation

The total number of operated ears was 379 This series includes also remobilizations

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Notwithstanding fracture, the results as to hearing improvement were good, especially in 1956—16 cases

TABLE III

NUMBER OF CASES WITH FRACTURE

	1954	1955	1956
I	—	2	3
II	2	3	13
III	8	6	5
IV	32	37	11
Total	42	48	32

LASTING RESULTS

The second, and most important point to be considered when dealing with the mobilization procedure, is the permanency of the result The patients in our series were from different parts of Finland, and, unfortunately not nearly all of them could be studied by follow-up examinations, therefore, it is not possible to present any definite percentages illustrating the permanency of the results

Table IV, however, shows data on the cases in which the hearing subsequently receded

The above Table shows that in Group I, in which the hearing gain was close to the theoretically possible level, the hearing usually did not deteriorate within the first 100 days after the operation During a longer period of observation cases with lost improvement occur also in this group In Groups II and III, on the other hand, the majority of the cases which lost the obtained improvement did so within a comparatively short period The next table (Table V) shows the percentage of cases with maintained improvement, lost improvement, and with lacking follow-up data in the years studied

Naturally, the initial result as to the amount of hearing gain differed in these various groups To obtain a more uniform basis of reference we, therefore, present the initial results in relation to the theoretically obtainable level The cases were divided into four groups, according to the result achieved In Group I the improvement rose to the theoretically possible level, or very close to it, postoperatively the loss by air was 0-10 db greater than the preoperative bone conduction loss after adjustment of the Carhart notch In Group II the gap between the postoperative air conduction and the preoperative bone conduction curve was 15-20 db , in Group III 25 db or more, and in Group IV there was no improvement whatever The results are shown in Table II

TABLE II

PRIMARY RESULTS—COMPARISON OF POSTOPERATIVE AIR CONDUCTION AND PREOPERATIVE BONE-CONDUCTION

I Postoperative AC-loss 0 10 db >preoperative BC-loss
II Postoperative AC-loss 15 20 db >preoperative BC loss
III Postoperative AC-loss 25 db >preoperative BC-loss
IV No Results

	1954	1955	1956	Total
I	12—11 8%	21—15 4%	23—16 2%	56—14 7%
II	29—28 6%	29—21 3%	64—45 0%	122—32 3%
III	18—17 8%	22—16 2%	32—22 6%	72—19 0%
IV	42—41 8%	64—47 1%	23—16 2%	129—34 0%
	101	136	142	379

In the above Table, attention is called to the fact that the proportion of cases in Group I has remained practically unchanged In spite of changes in the operative technique the percentage of cases with an excellent result has not increased appreciably In Group II, in which the gain is still good, similar to that obtained by a successful fenestration, a distinct improvement was noted in 1956 It is quite obvious that improved visual exposure and the substitution of direct footplate mobilization for the previous indirect method have caused an increase in the cases of this group, similarly, the proportion of complete failures has been considerably reduced, as compared with the preceding years

Despite the advances in technique, it was not possible to avoid crural fractures entirely, however, the adoption of direct footplate mobilization has reduced the importance of fractures. This is evident from Table III, in which the number of cases with fracture is shown in the different groups of hearing improvement.

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	1954	1955	1956	Total
I	12—11.8%	21—15.4%	23—16.2%	56—14.7%
II	29—28.6%	29—21.3%	64—45.0%	122—32.3%
III	18—17.8%	22—16.2%	32—22.6%	72—19.0%
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Despite the advances in technique, it was not possible to footplate to the anterior crus, but frequently the footplate is fixed also posteriorly. By applying pressures on these two points, it is possible to mobilize the footplate. Rarely is it necessary to free the footplate along its superior and inferior margins.

Advances in operative technique create an increase in the number of good initial results, as indicated by our figures for 1954, 1955, and 1956. In 1956 the initial result was good in about 60 per cent of the cases, and in only 17 per cent was there no improvement whatever. On the other hand, it should be noted that a result corresponding to the theoretically possible level was obtained in only about 16 per cent, in which footplate mobilization can thus be considered to have been complete. In 44 per cent the result was good, though it did not reach the theoretically possible level. In some of the cases this was due to fracture of a crus, or both crura, which reduces the effective movements of the footplate in spite of its mobilization. In some cases, however, the footplate evidently had not been completely mobilized.

TABLE V

PERMANENCY OF RESULTS (Up to March, 1957)

	1954	1955	1956
Improvement lost	31—52.5%	29—40.3%	24—20.2%
No follow up data	21—35.6%	22—31.6%	52—43.7%
Maintained improvement	7—11.9%	21—28.1%	43—36.1%
	59	72	119

The fact that in such cases mobilization may have been incomplete, is supported by the observation that this group, in which the initial result was good but did not reach the theoretically possible level, included cases receding to the preoperative level within a very short period of observation. In the group with the best initial result the hearing gain was maintained much longer, and if hearing subsequently receded, deterioration began much later. *From this it is apparent that not even the best primary result insures a lasting restoration of hearing,* but it would seem that the more incomplete

This Table shows that the number of cases in which improvement is lost, increases with the duration of the observation period A more detailed presentation of the lasting results is impossible, because of the great number of cases in which follow-up examination could not be carried out The figures in the Table obviously do not do full justice to our results as far as lasting restoration of hearing is concerned

CONCLUSIONS

In own experience, success of a mobilization operation is gained primarily by an exposure that allows good visualization of the region of the oval window It is only by watching the movement of the stapes footplate that the completeness of mobilization can be appraised The fact that a corresponding movement is seen in the membrane or niche of the round window does not yet insure that the footplate has been fully freed The stapes footplate must be readily and freely moveable in all possible directions on gentle manipulation

TABLE IV

IMPAIRMENT TO PREOPERATIVE LEVEL

	1954			1955			1956		
Days	I	II	III	I	II	III	I	II	III
0 100	–	3	8	–	5	13	–	4	9
100 200	–	3	3	–	1	2	–	5	4
200 300	–	3	1	1	–	–	–	2	–
300 400	2	4	–	1	–	–	–	–	–
400 500	–	–	–	1	1	–			
500 600	–	–	–	–	–	–			
600 700	–	1	–						
700	3	–	–						
Total	5	14	12	3	7	15	–	11	13
Total No of ears operated	12	29	18	21	29	22	23	64	32

Sometimes the fixation of the stapedial footplate is very slight Mobilization is then easy, and can be successfully performed with almost any technique If, however, the footplate is rigidly fixed, we consider a procedure directed at the footplate itself, the only correct one Fixation is usually most solid at the anterior periphery of the attachment of the footplate to the anterior crus, but frequently the footplate is fixed also posteriorly By applying pressures on these two points, it is possible to mobilize the footplate Rarely is it necessary to free the footplate along its superior and inferior margins

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GENERAL ANESTHESIA IN BRONCHOSCOPY, ESOPHAGOSCOPY AND LARYNGEAL SURGERY EMPLOYING THE EMERSON "RAINCOAT" RESPIRATOR*

SYLVAN M SHANE, D D S ,
HARRY ASHMAN, M D ,
ALVIN WELFELD, M D ,
JEROME SNYDER, M D ,
ELLIOTT MICHELSON, M D ,
and
DONALD NAVRATIL, M D ,
Baltimore, Md

Because of the many difficulties associated with general anesthesia when employed for peroral endoscopy, local analgesia, although not necessarily the patient's choice, has remained the endoscopist's choice in these procedures

There have been numerous general anesthesia techniques described,[1 2 3 4] which have sought to resolve the major problem of maintaining adequate respiratory exchange in a deeply anesthetized or curarized patient, with the surgeon working in the zone of anesthesia administration All of these methods have the basic physiologic fault of inadequate ventilation with retention of carbon dioxide

This problem has now been resolved by the use of a modified polio chest respirator, which efficiently maintains respiratory exchange in a lightly anesthetized but totally curarized patient

The respirator consists of a plastic or rubber raincoat, which slips over the patient's head and trunk It fits snugly around the neck and wrists A wire cage is placed under the raincoat so that there is at least a six-inch space between the

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*From the Departments of Anesthesiology Otolaryngology and Surgery The Lutheran Hospital of Maryland Baltimore 16 Md

Editor s Note This manuscript received in The Laryngoscope Office and accepted for publication August 12 1957

the mobilization, the more rapidly and frequently does the hearing return to the preoperative level

We still consider the stapes mobilization operation an acceptable surgical procedure worth developing further, and we regularly perform it first when operating on patients with clinical otosclerosis If no result is obtained, we then resort to fenestration

Haartmanink 4

SEVENTH INTERNATIONAL CONGRESS OF BRONCHOESOPHAGOLOGY

The Seventh International Congress of Bronchoesophagology will be held at Kyoto (Japan) University, September 12-14, 1958, under the direction of Prof Mituharu Goto, M D , Otorhinolaryngological Clinic, Kyoto University Hospital, Kyoto, Japan

A registration fee of $25 00 U S A will be charged all physicians and a fee of $10 00 for wives or non-medical guests Registered members are admitted free to banquet, receptions and sightseeing tours

Closing date for scientific papers will be April 30, 1958 A summary of paper, not to exceed 800 words, should be sent to the Director not later than that date

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raincoat and the patient's chest (see Fig 1) The raincoat is then tucked in snugly between the thighs A two-inch opening rimmed with rubber is located in the chest region of the raincoat, to which can be attached the suction hose from a specially designed vacuum pump This has been fitted with a valve that permits it not only to create, very rapidly, an intense vacuum by sucking air out of the raincoat enclosed area, but also alternately permits air to reenter the

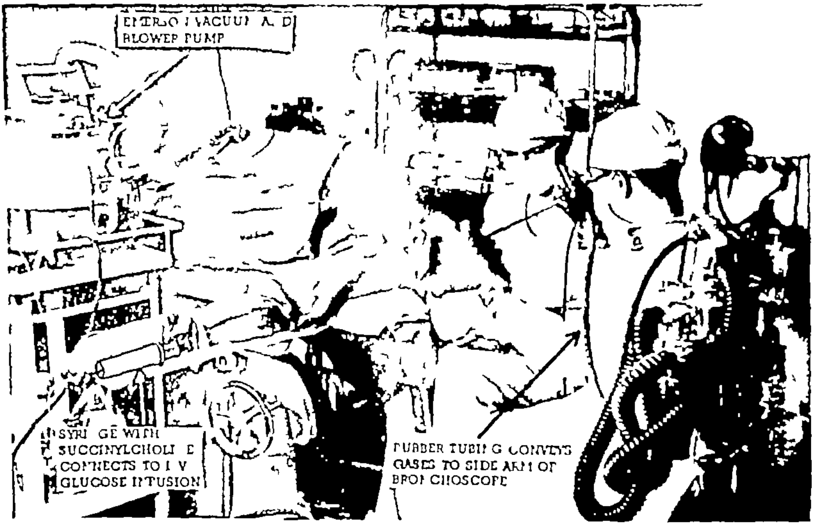
EMERSON VACUUM AND BLOWER PUMP
SYRINGE WITH SUCCINYLCHOLINE CONNECTS TO I V GLUCOSE INFUSION
RUBBER TUBING CONVEYS GASES TO SIDE ARM OF BRONCHOSCOPE

Fig 1 Bronchoscopy Patient is maintained in state of total paralysis by intermittent I V injections of succinylcholine Light anesthesia is maintained by insufflating a mixture of N_2O+O_2+Cyclo through side arm of bronchoscope Patient's head held by assistant Respirator will maintain efficient respiratory exchange indefinitely Leakage around patient's neck wrist and thighs is minimal and of little significance since vacuum causes raincoat to adhere to skin

area, thus establishing a ventilation pattern which maintains not only tidal volume, but may even be used to hyperventilate the patient The suction causes expansion of the chest wall which produces inhalation, while the alternate re-entrance of air back into the cage causes the chest to fall, producing exhalation A patient lightly anestheteized and totally paralyzed with succinylcholine can thus be ventilated with complete efficiency

There is no limitation to the length of time the operator can work, and he can proceed in a leisurely and thorough manner, not being hurried by discomfort or fear for the condition of the patient A laryngoscope with a Lewy laryngoscope holder (see Fig 2) can be rested on the patient's chest wall, thus allowing operations on the larynx while the operator has two hands free for maneuvers With succinylcholine the larynx is at rest in abduction, leaving the free margins of the vocal cords along with the subglottic region easily visible

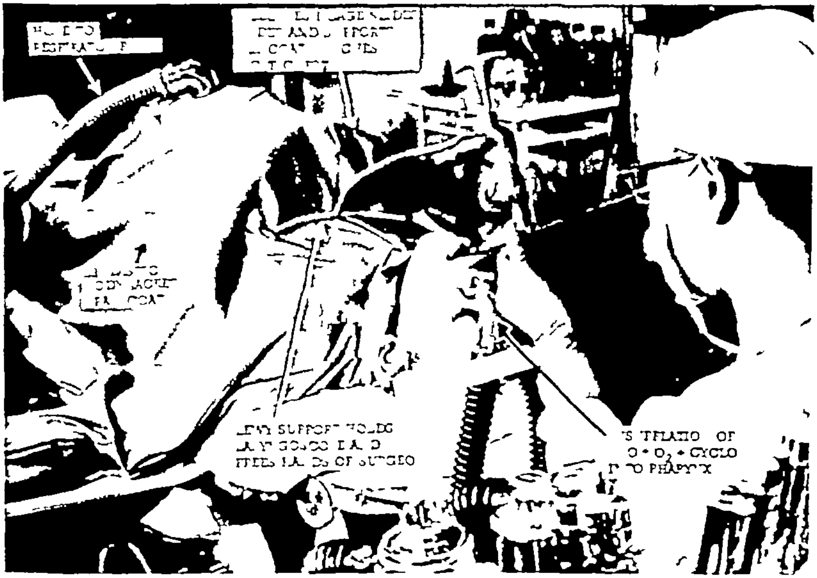

Fig 2 Laryngeal Surgery Light anesthesia is maintained by insufflating N_2O+O_2+Cyclo through a naso-pharyngeal tube the tip of which lies at the uvula Paralysis is maintained by intermittent injections of succinylcholine A Lewy support holds laryngoscope which frees surgeon's hands Respirator breathes for patient by creating first a negative then a release of pressure around chest wall

Esophagoscopies are facilitated and safer on a completely relaxed patient with better visibility and less chance of traumatic perforation

Bayuk[5] was the first to describe the use of a polio chest shell for maintaining respiratory exchange in curarized patients subjected to peroral endoscopy, however, the chest raincoat and the patient's chest (see Fig 1) The raincoat is then tucked in snugly between the thighs A two-inch opening rimmed with rubber is located in the chest region of the raincoat, to which can be attached the suction hose from a specially designed vacuum pump This has been fitted with a valve that permits it not only to create, very rapidly, an intense vacuum by sucking air out of the raincoat enclosed area but also alternately permits air to reenter the

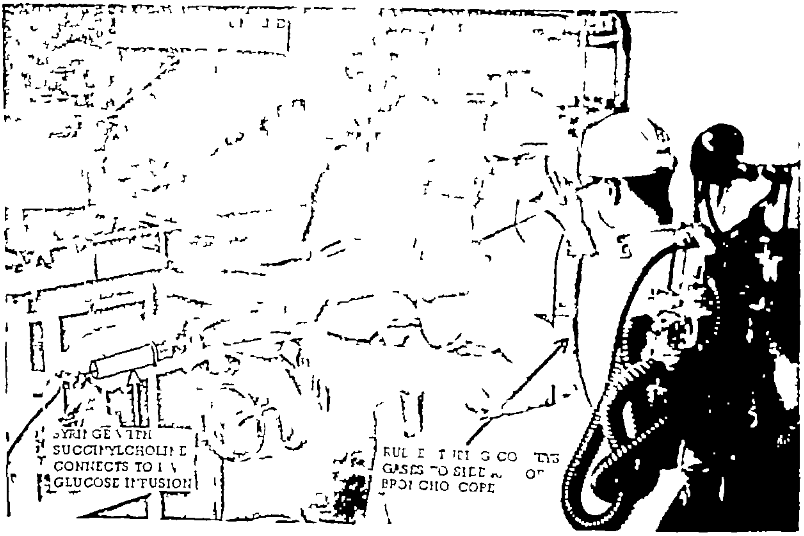

Fig 1 Bronchoscopy Patient is maintained in state of total paralysis by intermittent I V injections of succinylcholine Light anesthesia is maintained by insufflating a mixture of N_2O+O_2+Cyclo through side arm of bronchoscope Patient's head held by assistant Respirator will maintain efficient respiratory exchange indefinitely Leakage around patient's neck wrist and thighs is minimal and of little significance since vacuum causes raincoat to adhere to skin

area, thus establishing a ventilation pattern which maintains not only tidal volume, but may even be used to hyperventilate the patient The suction causes expansion of the chest wall which produces inhalation, while the alternate re-entrance of air back into the cage causes the chest to fall, producing exhalation A patient lightly anesthetized and totally paralyzed with succinylcholine can thus be ventilated with complete efficiency

There is no limitation to the length of time the operator can work, and he can proceed in a leisurely and thorough manner, not being hurried by discomfort or fear for the condition of the patient A laryngoscope with a Lewy laryngoscope holder (see Fig 2) can be rested on the patient's chest wall, thus allowing operations on the larynx while the operator has two hands free for maneuvers With succinylcholine the larynx is at rest in abduction, leaving the free margins of the vocal cords along with the subglottic region easily visible

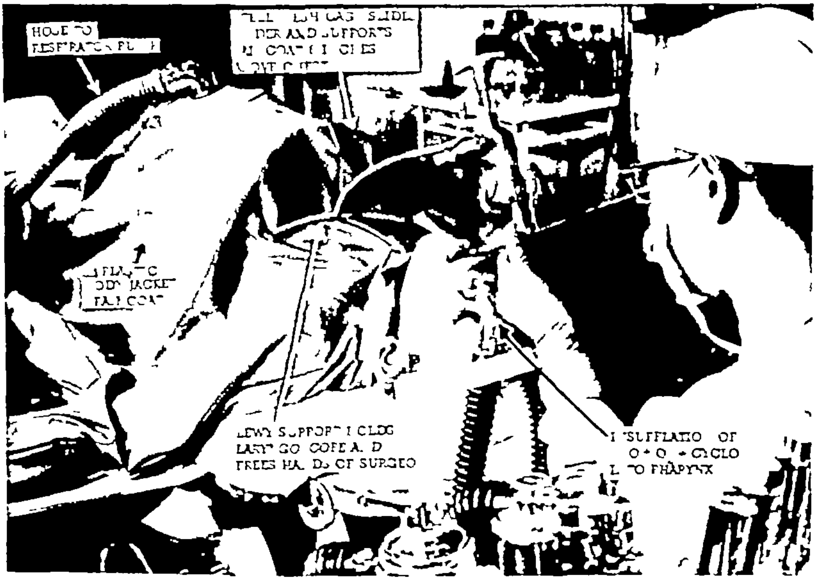

Fig 2 Laryngeal Surgery Light anesthesia is maintained by insufflating N O+O +Cyclo through a naso-pharyngeal tube the tip of which lies at the uvula Paralysis is maintained by intermittent injections of succinylcholine A Lewy support holds laryngoscope which frees surgeon s hands Respirator breathes for patient by creating first a negative then a release of pressure around chest wall

Esophagoscopies are facilitated and safer on a completely relaxed patient with better visibility and less chance of traumatic perforation

Bayuk[5] was the first to describe the use of a polio chest shell for maintaining respiratory exchange in curarized patients subjected to peroral endoscopy, however, the chest shell elevates and depresses only the anterior portion of the chest wall, and does not produce the large tidal exchange possible with the Emerson plastic "raincoat" cage

BRONCHOSCOPY

The patient first dons the plastic raincoat, or poncho, and after placing the steel mesh cage over the chest (under the raincoat) the neck and arm strings are tightened to prevent leakage of air in or out An intravenous glucose infusion is first established so that a patent vein will always be available to maintain succinylcholine paralysis

The patient is then lightly anesthetized by any favorite method, then rendered apneic by succinylcholine and the respirator turned on The bronchoscope is then passed into the trachea while oxygen, with anesthetic gases are continuously administered through the side-arm of the instrument It is advisable to pass the bronchoscope quickly, since the extreme relaxation may produce obstruction of the glottis because of a relaxed epiglottis It is sometimes more efficient to pass the bronchoscope through a laryngoscope for this reason Adequate exchange prevails throughout the state of paralysis If the patient reflexly moves additional succinylcholine is injected

LARYNGEAL SURGERY AND ESOPHAGOSCOPY

In laryngeal surgery anesthetic gases must be administered by insufflation to maintain unconsciousness, and this is done by means of a nasopharyngeal tube, which does not enter the trachea

For laryngoscopy and laryngeal surgery the vocal cords are continuously under direct observation since they are the surgical target, and patency of the airway is thus assured by direct vision

In esophagoscopy, on the other hand, airway patency is not assured, and partial obstruction may exist even though the respirator is operating efficiently In order to assure airway patency during esophagoscopy a stethoscope should be attached to the patient's neck at the larynx with adhesive, so that ventilation can be continuously monitored This is essential, since succinylcholine paralysis produces complete relaxation of the tongue, which often falls posteriorly to obstruct the airway even though the esophagoscope is in place In order to prevent tracheal collapse from the instrument, an endotracheal tube may be inserted via the nose prior to introducing the esophagoscope, and the anesthetic gases delivered through this naso-endotracheal tube

ANESTHESIA TECHNIQUE

Patients may be induced with methitural (Neraval), hexobarbital (Evipal), or thiopental (Pentothal) We prefer methitural, since there is less postoperative inebriation In addition, the return to consciousness occurs much more rapidly than with the other barbiturates

The induction dose of the three drugs in the average adult is

Methitural—10 cc of a 4 per cent solution

Hexobarbital—10 cc of a 4 per cent solution

Thiopental—8 cc of a 4 per cent solution

As soon as the methitural is injected a mask is placed on the patient's face, and a mixture of nitrous oxide, cyclopropane and oxygen is administered in a semi-closed system as follows

Cyclopropane—700 cc per minute (11 7 per cent)

Nitrous oxide—2000 cc per minute (29 8 per cent)

Oxygen—4000 cc per minute (58 5 per cent)

This mixture of gases will produce light, plane I anesthesia within three to five minutes, and no matter how long it is administered a level of anesthesia deeper than plane I will be impossible to achieve We have used this exact mixture in over 30,000 patients during the past nine years for every type of surgery Details of its administration have been described fully elsewhere[6-8]

When plane I is established, 20 mg of succinylcholine is injected through the intravenous infusion needle At the occurrence of respiratory arrest the Emerson respirator is turned on, and the breathing bag on the anesthesia machine is observed so that inflation and deflation occurs with each respiratory cycle While still under succinylcholine paralysis the mask is removed from the face, and the bronchoscopist inserts the bronchoscope quickly To the side-arm tube of the bronchoscope is attached a piece of wide bore rubber tubing through which is insufflated exactly the same mixture of nitrous oxide, oxygen and cyclopropane If the patient should reflexly move, or if added relaxation is requested, an additional cc of succinylcholine (20 mg) is injected intermittently whenever necessary When the operation is over, pure oxygen is insufflated through the bronchoscope for about two minutes prior to removing it When the patient's own respiratory efforts resume the Emerson respirator is turned off

For laryngeal surgery the same mixture of gases is insufflated through a nasopharyngeal tube which is inserted through the nose, only to the uvula In esophagoscopy a stethoscope should be taped to the neck in the region of the larynx so that respiratory exchange can be monitored, in the event an endotracheal tube is not used

SUMMARY

A new method of assuring adequate ventilatory exchange during bronchoscopy, esophagoscopy and laryngeal surgery under light general anesthesia, with full curare paralysis, has been described An Emerson body jacket raincoat over a steel mesh cage is employed in conjunction with a special vacuum pump respirator to provide intermittently expansion and compression of the chest wall, which thereby assures efficient ventilation

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and their treatment, as well as the technique of the various procedures is considered

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PROGRAM OF THE SEVENTH INTERNATIONAL CONGRESS OF BRONCHOESOPHAGOLOGY

Meeting Place—Kyoto University, Kyoto, Japan

Friday, September 12th, 1958

8 00 P M -10 00 P M —Reception (Party) Shimomura House in Kyoto

Saturday, September 13th

8 00 A M —Inaugural Session (in Kyoto University Hall)

9 00 A M -12 00 M —First Scientific Session

12 00 M -2 00 P M —Luncheon (Reception The Place not decided)

2 00 P M -6 00 P M —Sightseeing in Kyoto

8 00 P M —Banquet, Miyako Hotel

Sunday, September 14th

8 00 A M -11 30 A M —Second Scientific Session

11 30 A M -12 00 M —Closing Ceremony

12 00 M —Departure for sightseeing in Nara

1 00 P M —Luncheon, Nara Hotel

2 00 P M -6 00 P M —Sightseeing in Nara

7 00 P M —Return to Kyoto

INTRA-AURAL MUSCLE CONTRACTION IN MAN, EXAMINED BY MEASURING ACOUSTIC IMPEDANCE OF THE EAR*

AAGE R. MØLLER,
Stockholm, Sweden

INTRODUCTION

Inasmuch as the intra-aural muscles appear to be of some importance to the function of the ear, it is desirable to understand their behavior in greater detail. The contraction takes place bilaterally when one ear is stimulated by a strong tone, with a minute, but clearly measurable, delay in relation to the stimulating tone. The latent period before the reaction of the muscles is significant, in that the muscles must be regarded as inactive during this latency. The majority of the knowledge we have concerning the function of the intra-aural muscles has been obtained from animal experiments, as it has been difficult to study the action of the muscles in man. Usually the stimulus has been applied to one ear, while the other ear has been used for measuring the muscle contraction.

A report will be made here of an investigation of the contraction of the intra-aural muscles in man, carried out by using measurement of the acoustic impedance in the external auditory canal. Both the latent period of a contraction, shown as a change in impedance, and the degree of the impedance change as a function of the intensity of the stimulus will be studied.

EARLIER INVESTIGATIONS

The function of the intra-aural muscles has been studied by many writers. The majority reach the conclusion that a muscle contraction causes a decrease in transmission, espe-

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*From the Speech Transmission Laboratory, Department of Telegraphy and Telephony at the Royal Institute of Technology (Chairman Prof. T. Laurent), Stockholm, Sweden.

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cially with lower frequencies Hallpike and Smith observed that a muscle contraction effects a decrease of the cochlear potential in cats Wiggers (1937) studied guinea pigs, in which spontaneous contractions of the intra-aural muscles occur under light urethan anesthesia, and found a drop in the cochlear potential at lower frequencies when the muscles contracted At 400 c/s a decrease of 20 db was observed, at 1100 c/s there was no change, and at 1500 c/s an increase in the transmission took place when the intra-aural muscles contracted Above 2000 c/s there was no change Galombos (1942) investigated bats and found activity of the intra-aural muscles at frequencies up to 55 kc/s Death or anesthesia increased the cochlear potential for a strong signal, and this was taken by the writer to indicate that the intra-aural muscles affect a reduction in the transmission, and that the cochlear potential, therefore, increased when the muscles relaxed because of death or anesthesia Wever and Vernon (1954) studied the cat, measuring the cochlear potential and finding that the reduction in transmission was very slight above 500 c/s but increased below that frequency The writers state that the stimulating tone was only about 2 db above the contraction threshold They observed, moreover, that the drop in transmission increased when the intensity of the stimulus was increased When the stimulus was 20 db above the contraction threshold, a reduction of about 20 db was observed at 300 c/s The stimulus frequency was 1000 c/s With only tensor tympani active (with the stapedius tendon severed) there was practically no reduction in the transmission

Metz observed that a contraction of the intra-aural muscles effects a change in the impedance of the ear He found that the transmission reduction can be measured as a change in impedance in the external auditory canal, principally as a change in absorption The angle of the reflection co-efficient remained almost constant during a muscle contraction Using the same method, Jepsen studied the threshold value for a muscle contraction in relation to the auditory threshold In order to determine which muscle caused the change in absorption, he examined seven patients with facial nerve paralysis, but was unable to demonstrate any change in impedance accompanying stimulation of the contralateral ear On the other hand he observed a normal impedance change in two patients with trigeminal paralysis This he accepted as proof that the cause of a change in sound absorption is a contraction of the stapedius muscle and not of the tensor tympani Jepsen further demonstrated that the threshold for muscle contraction observed with help of impedance measurement agrees closely with that obtained visually by observance of the stapedius tendon through a perforation in the tympanic membrane

The various earlier studies of the latent period for a contraction of the intra-aural muscles were carried out, using a variety of methods which are reflected in the results Kobrak (1930) studied rabbits and used flute tones as stimuli As indicators for muscle contraction he employed myographs attached to the tendons of the muscles He obtained a latency of between about 30 and 150 msec for the contraction of the stapedius, and between about 75 and 150 msec for the tensor tympanic Lorente de No (1935) studied the contraction of the tensor tympanic in rabbits under ether anesthesia He used, as did Kobrak, myographs as indicators, but employed a better-defined stimulus in the form of a tone produced by a loudspeaker As a result he obtained a latency of approximately 20 msec when the stimulus was about 15 db above the contraction threshold When the stimulus was more than 35 db above the contraction threshold, he observed a latent period of from 12 to 13 msec

Tsukamoto (1934) examined rabbits under light urethan anesthesia He used change in pressure in the labyrinthine fluid as an indicator of the contraction of the intra-aural muscles, recorded with the help of a capillary tube He used a flute tone as stimulus With this method he found a mean latency of 370 msec

Perlman and Case (1939) registered action potentials from the tendon of the stapedius muscle in man in a contraction of the stapedius caused by stimulation with a tone at 1000 c/s applied to the contralateral ear The intensity of this tone is described by the writers as "loud" Their results obtained on a number of experimental subjects gave a mean latency of

10 5 msec Bornschein and Krejci studied rabbits, registering action potentials from the tensor tympanic muscle The experimental animals were under local anesthesia A click was used as stimulus The latent period was found to be 12 to 13 msec

Lorente de No and Bornschein and Krejci observed that the contraction of the intra-aural muscles in rabbits exhibited rhythmic changes (waves) in muscular tension and action potential, respectively The frequency of these changes was

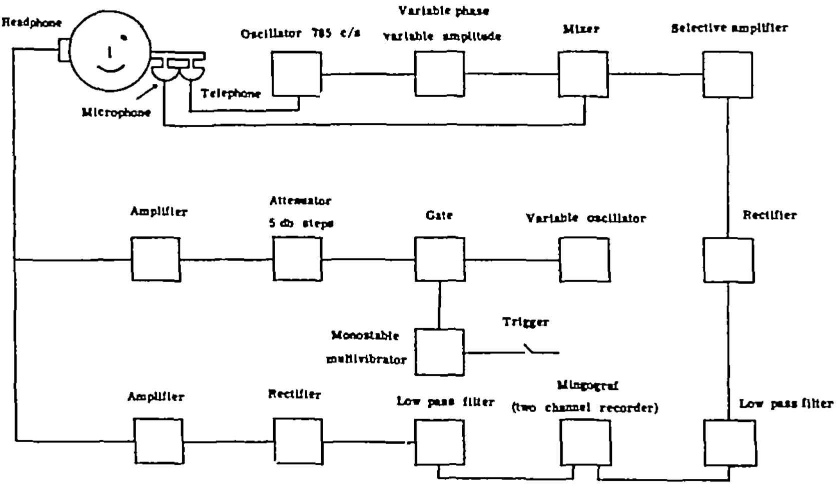

Fig 1 Block-scheme of complete equipment

15 to 20 c/s according to Lorente de No, and 15 c/s according to Bornschein and Krejci

Metz (1951) investigated the latency of contraction in the intra-aural muscles in man by recording changes in the acoustic impedance of the ear, measured by means of a so-called Schuster bridge He observed that the latent period was dependent upon the intensity of the stimulus A stimulus 80 db above the threshold of hearing gave a latency of 150 msec, 90 db above gave 50 msec, and 100 db above gave

In order to find a closer relation between the latent period
a latency of 40 msec

and the intensity of the stimulus, as well as the variation in the results from person to person, the present investigation, using impedance measurement, was started The reproducibility of the measurements was also investigated

INSTRUMENTATION

The equipment used was designed to deliver a stimulating tone of known frequency and intensity and to indicate a muscle contraction A muscle contraction was shown by recording changes in the acoustic impedance of the ear The acoustic impedance was measured at a frequency of 785 c/s

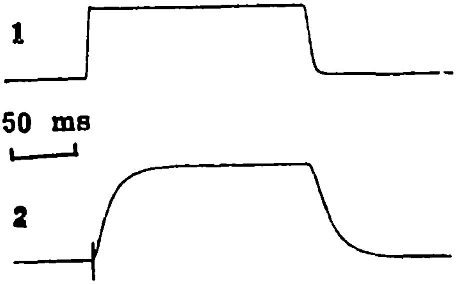

Fig 2 a Pulse response of the selective amplifier The upper curve (1) represents a tone-pulse (785c/s) applied to the input of the amplifier and the lower curve (2) represents the output from the amplifier Both signals are rectified and low-pass filtered with 100 c/s cut-off frequency

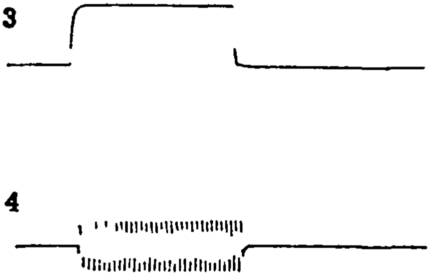

Fig 2-b The wave form of the stimulus pulse (3) is stimulus 2500 c/s rectified and low-pass filtered with 700 c/s cutoff frequency (4) is stimulus 250 c/s direct recorded

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[a] Fig 1 shows a block scheme of the equipment used Stimuli are produced by means of an earphone of Permoflux type PDR 10 The signal to the earphone is delivered by an oscillator with variable frequency which feeds the earphone via a gate circuit and an attenuator A signal from a monostable multivibrator opens the gate in a manner that prevents the occurrence of a click The curve form of the tone pulse produced by the gate circuit is shown in Fig 2

The impedance change is indicated by means of a special measuring device consisting of a telephone and a microphone both connected to a tube 4 mm in diameter which is inserted into the auricular canal A signal at 785 c/s is fed to the telephone The output voltage of the microphone represents the acoustic impedance in the ear measured in the external auditory canal The output voltage is compared with a variable voltage having the same frequency When this voltage has the same amplitude as the voltage arriving from the microphone and opposite phase the reading is 0 When the acoustic impedance changes the voltage from the microphone also changes and the resulting reading

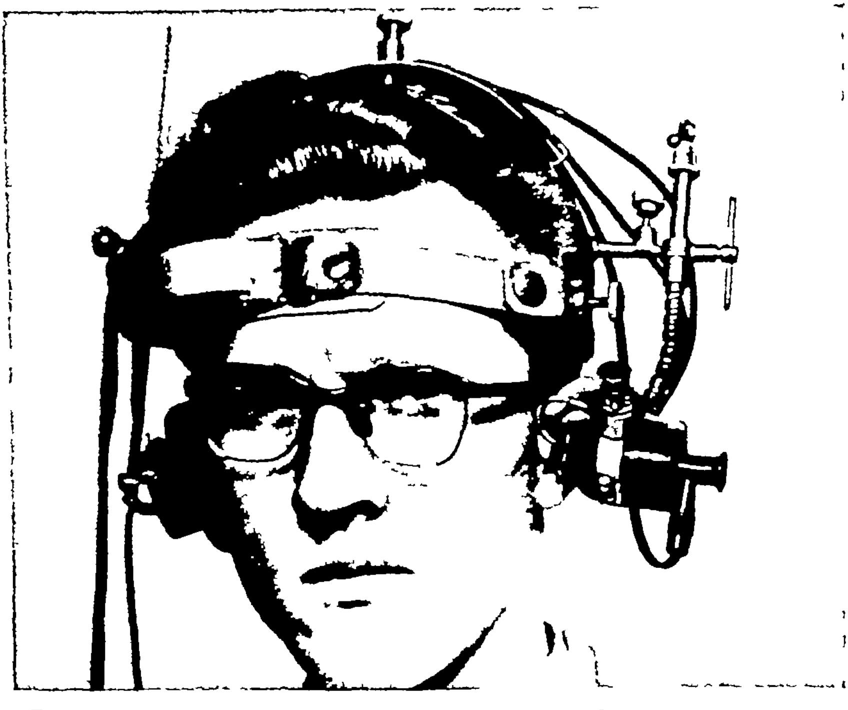

Fig 3 The arrangement of headphone and impedance measuring unit in position on experimental subject

will no longer be 0 This voltage corresponds to a change in impedance which is the result of a muscle contraction The signal is amplified rectified and filtered before it is fed into one channel of the recorder In addition the signal to the earphone is amplified in the same manner as the signal that indicates a muscle contraction and is thereafter fed to the other channel of the recorder The latency is then evident as the time difference between these two signals The prerequisite for this is that the apparatus be corrected for possible variations in the location of the loops in the recorder and for delay in the selective amplifier amplifying the signal indicating a muscle contraction The delay in the two low pass filters used to filter the rectified signal has no significance as the filters are the same in the two channels Fig 2 shows the curve form of an interrupted signal at 785 c/s, before and after amplification in the selective amplifier recorded after rectification and filtration with

100 c/s low pass filters in both channels (1) and (2) The curve form of a stimulus impulse is shown concurrently (3) The pulse shown is a rectified signal at 2500 c/s filtered only by the low pass filtering action of the recorder This means that the signal is distorted very little by the filters Below this a stimulus signal at 250 c/s is reproduced directly (4) The recorder used (Mingograf) is a two channel writing recorder in which a fine ink jet traces a curve on ordinary adding machine paper The frequency range of the recorder runs from direct current to 700 c/s The paper feed rate used was 20 cm/sec in latency measurements and 5 cm/sec in registration of waves in the muscle contraction The impedance measurement apparatus gives a sound pressure of about 75 db re 0 0002 dyne/cm^2 This is measured with subjective comparison

b The same equipment was used in measurement of absorption as a function of the stimulus intensity, except that the output of the microphone was measured directly in amplitude relation and phase relation to the voltage applied to the telephone The voltage (E) from the microphone is in the following relation to the acoustic impedance Z_m

$$Z_m = k\,E\,, \qquad Z_m = \frac{Z\,Z_1}{Z + Z_1}\,, \qquad Z = \frac{Z_m\,Z_1}{Z_1 - Z_m}\,,$$

and by using admittances

$$Y_m = \frac{1}{Z_m} = \frac{1}{kE}\,,$$

$$Y = Y_m - Y_1\,, \qquad \left(Y_1 = \frac{1}{Z_1} \text{ and } Y = \frac{1}{Z}\right),$$

The energy absorption *a* and the angle of reflection coeffecient *R* are determined from

$$\sqrt{1-a}\;e^{j\varphi R} = \frac{\dfrac{1}{Y\rho c} - 1}{\dfrac{1}{Y\rho c} + 1} = -\frac{Y\rho c - 1}{Y\rho c + 1}$$

or

$$\sqrt{1-a}\;e^{j\varphi R} = \frac{\dfrac{Z}{\rho c} - 1}{\dfrac{Z}{\rho c} + 1}\,,$$

$$a = 1 - \left|\frac{Y\rho c - 1}{Y\rho c + 1}\right|^2$$

where Z is the impedance of the ear and Z_1 is the internal impedance of the microphone-telephone unit The impedance of the ear is measured in the plane of the microphone The absorption is most easily determined with the help of a bipolar chart in which both impedance and admittance may be used The use of admittances is advantageous because when admittances rather than impedances are used, the only effect of the internal impedance of the microphone-telephone unit is to shift the axes In order to obtain the impedance of the ear in the plane of the tympanic membrane it is necessary only to subtract the number of degrees corresponding to the length of the tube from the microphone to the membrane The absorption in this bit of tube is so slight that it may be disregarded

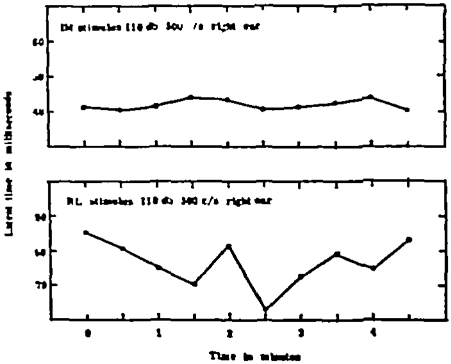

Fig 4 The variation in latent time for a series of 10 measurements made one every 30 seconds

MEASUREMENT OF THE LATENT PERIOD

Eight persons, ranging in age from 18 to 32 years, and all with normal hearing, were examined The experimental subject was seated in a chair in a sound-insulated room The stimulus was applied as a rule, to the right ear, and the impedance measuring unit was connected to the left ear Fig 3 shows the arrangement The tube from the impedance measuring device was introduced into the ear Vaseline was used to insure an airtight connection between the tube and the auricular canal In measurements of the latent period a stimulus about 125 msec in duration was applied every 30 seconds At least ten measurements were made at each intensity It has been demonstrated that the latent period is not constant In a series such as the one studied here, wide variations may be obtained (see Fig 4) It was for this reason that several measurements were made at each in-

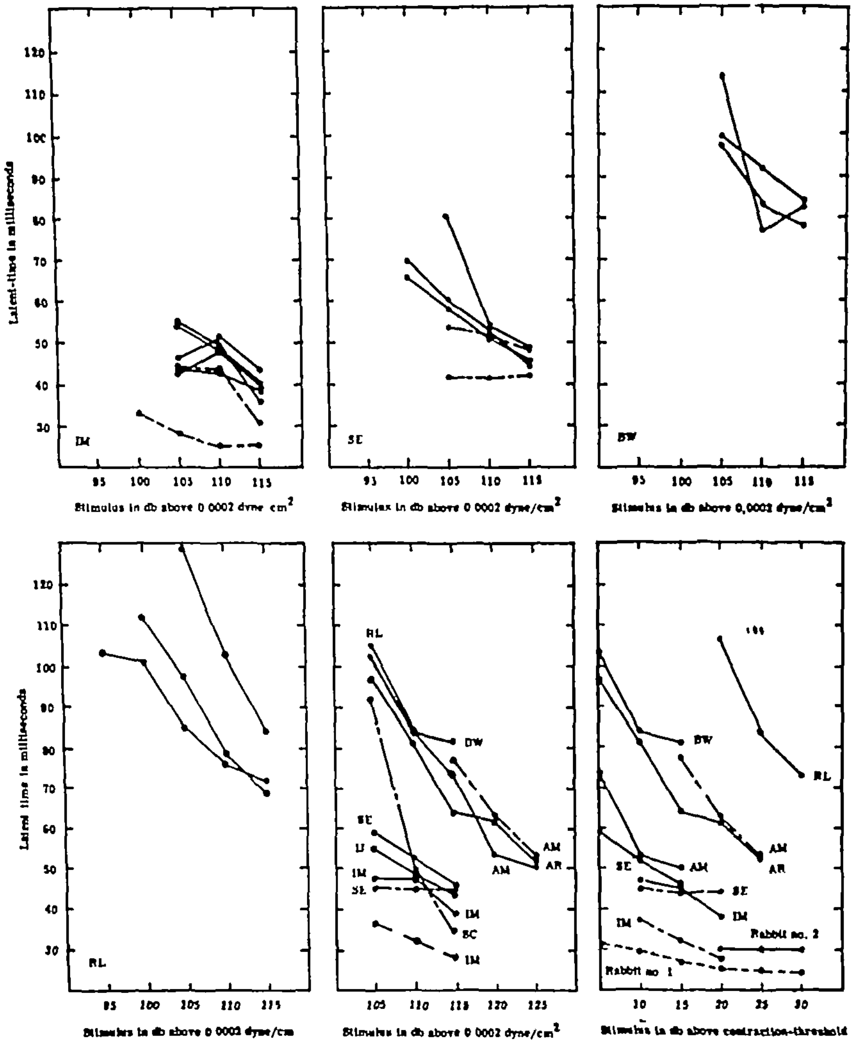

Fig 5 The relationship between latent-time and stimulus intensity for different persons Stimulus 1500 c/s broken line Stimulus 500 c/s solid line

tensity rather than only one for each stimulus intensity The latency has been defined as the mean value from a series of at least ten measurements Immediately after, the next series of measurements was started, with the lowest intensity first, succeeded by increasingly higher intensities This procedure was followed to avoid adaptation The stimulus frequencies used were 500 and 1500 c/s The test tone used for impedance measurement was not interrupted between measurements

Fig 5 shows the relation between the intensity of the stimulus and the latent period and the reproducibility of such measurements The different curves were recorded at intervals of several days It is evident that there is great variation from person to person The latency decreases as the stimulus increases at the same time that the reproductivity

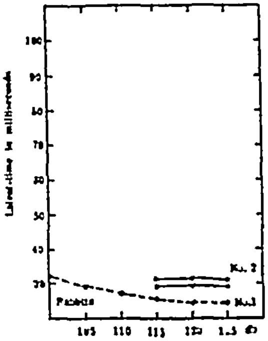

Fig 6 The relationship between latent-time and stimulus intensity for two rabbits (there is no reference here between the cited intensity and 0 0002 dyne/cm²)

of the measurements from day to day has a tendency to improve. The maximum and minimum latent time obtained was 130 and 25 msec It appears that 1500 c/s stimuli gave a shorter latent period than 500 c/s The intensity shown is re 0 0002 dyne/cm², measured in a 6 cc coupler, with the exception of the lower curve on the right (see Fig 5), where an attempt has been made to give the intensity relative to the threshold of muscle contraction This is rather unreliable, however, as the threshold value does not seem to be well defined, i e, the threshold is much higher before a contraction than shortly after The threshold discussed here was measured after a contraction caused by a tone somewhat higher than the threshold value

In measurements on rabbits the same technique was used as that employed in the measurements on human subjects, except that a tube was mounted on the telephone to carry the sound down into the rabbit's ear Moreover, 2000 c/s was used as stimulus frequency (see Fig 6) The tube on the impedance measuring unit was also longer The rabbits were placed on a table and held in a cloth bag An assistant held the telephone and impedance measuring unit in position The rabbits were not anesthetized The stated intensity of the stimulus was not re 0 0002 dyne/cm^2 in the measurements on rabbits because of the tube mounted on the telephone

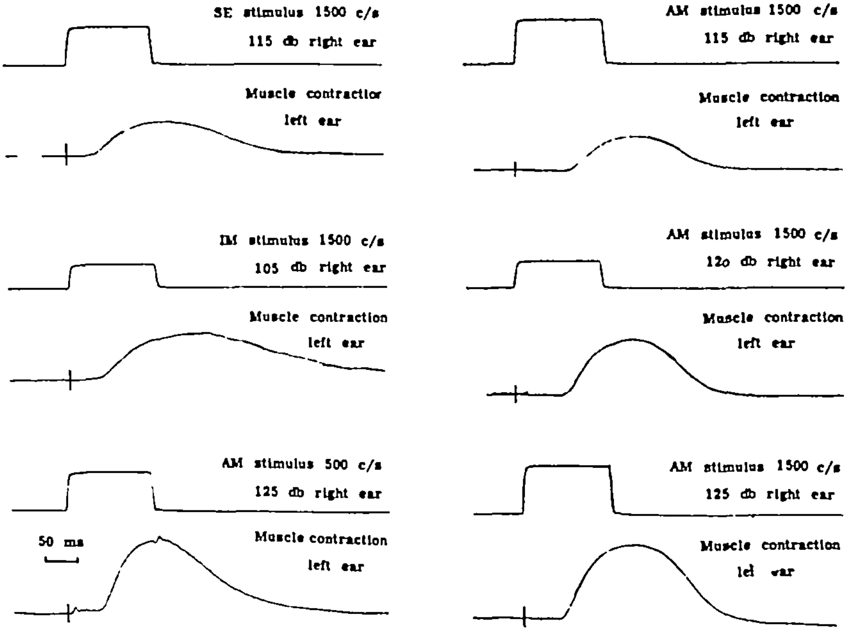

Fig 7 Examples of recorded muscle contractions

Fig 7 shows examples of the muscle contractions produced by the different intensities and in different persons The upper curve shows the stimulus and the lower curve shows the rectified signal that results from a muscle contraction The deflection shown need not be in any definite relation to the degree of muscle contraction This is because the registered signal occurs as the difference between the adjustable voltage and the output voltage of the microphone There is no simple relation between the output voltage of the microphone and the impedance or absorption of the ear. All that can be said is that when the microphone voltage changes it is due to a change in the impedance of the ear, and that may be due to a muscle contraction. It is not entirely impossible that a muscle contraction may take place without a change in impedance. Whether or not such a muscle contraction without a change in the impedance may be of any significance for sound transmission in the ear is uncertain.

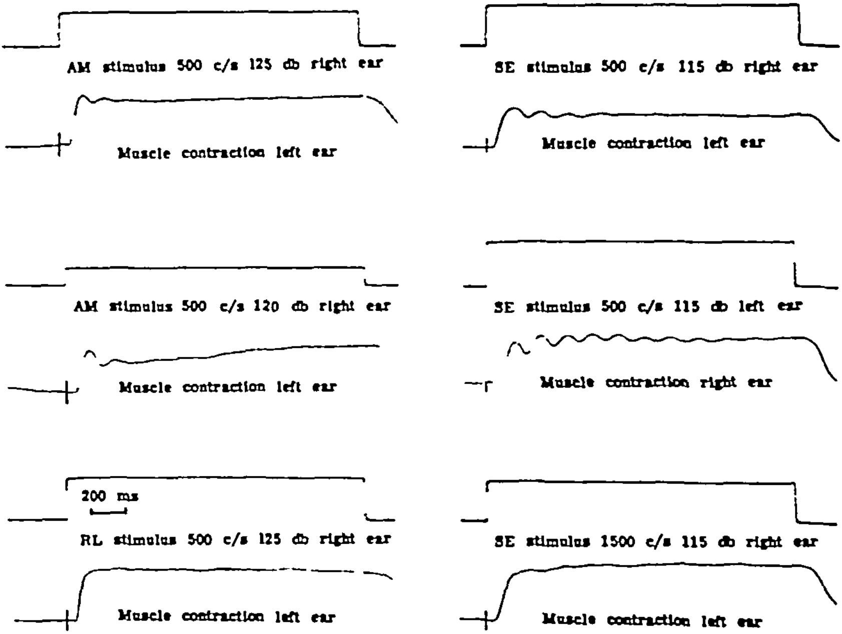

Fig. 8. Examples of recorded muscle contractions with waves in the beginning of the contraction.

Lorente de No has demonstrated in experiments on rabbits that waves occur with constant frequency in the muscle tension when the tensor tympanic contracts. A similar phenomenon was observed in three of the experimental subjects in this study, and was most pronounced in SE. The waves were not apparent in stimulation with 1500 c/s, but were a constant phenomenon with stimuli at 500 c/s in these three persons. Fig. 8 shows examples of such waves. The frequency was relatively constant and was about 7 c/s. (Lorente de No observed 15 and 20 c/s in rabbits) The measurements in this case were carried out according to the same principles as the latent period measurements The mean values of the ten measurements were

SE stimulus—110 db 500 c/s right ear	6 4 c/s
SE stimulus—110 db 500 c/s left ear	6 6 c/s
SE stimulus—105 db 500 c/s left ear	6 9 c/s
AM stimulus—120 db 500 c/s right ear	7 4 c/s
AM stimulus—120 db 500 c/s left ear	7 5 c/s
IM stimulus—110 db 500 c/s right ear	6 8 c/s

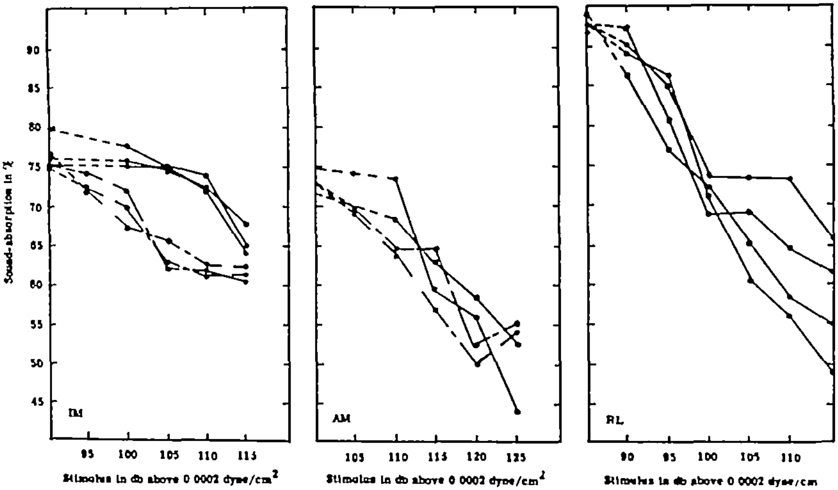

Fig 9 The relationship between stimulus intensity and sound absorption in the ear The broken lines are for stimulus 1500 c/s and the solid lines are for stimulus 500 c/s The points on the Y-axis which are connected with dotted lines to the curves indicate absorption without stimulus

Measurements on different days show that the reproductivity was extremely good

The experimental subjects remarked spontaneously that the stimulus tone was not constant in amplitude at the beginning of the stimulation when 500 c/s was used They heard a distinct change in amplitude on the occasions when waves were registered in the impedance change The persons who did not exhibit these waves could not hear variations in the amplitude, not even when they had been instructed to listen for them

Fig 9 shows the sound absorption as a function of the intensity of the stimulus for three different persons, measured in the external auditory canal with a measuring frequency of 785 c/s The different curves come from measurements on different days The first is the lowest stimulus intensity used, followed by the next lowest and so on The impedance changes in a muscle contraction appear to be a change in absorption without a change in the angle of the reflection co-efficient The measurements show that a muscle contraction causes a decrease in the sound absorption, which takes place gradually as the stimulus increases

SUMMARY

The latent time for the contraction of the intra-aural muscles is measured in eight persons with normal hearing The muscle contraction is demonstrated with impedance measurement The latent time is defined as the mean of at least ten successive measurements at 30-second intervals A wide variation in the results was obtained with respect to measurements, both on different persons and on the same person, with intervals of several days between measurements For comparison, similar measurements were carried out on two rabbits A phenomenon worthy of note was the observance of waves in the muscle contraction in three of the experimental subjects during stimulation at 500 c/s The relation between the stimulus intensity and the sound absorption is investigated in three experimental subjects These studies demonstrate that the muscle contraction causes a decrease in the sound absorption without a change occurring in the angle of the reflection co-efficient and that the decrease in absorption occurs gradually as the intensity of the stimulus increases

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AMERICAN BOARD OF OTOLARYNGOLOGY

The American Board of Otolaryngology will conduct only one examination in 1958, and this will be October 6-9, 1958, in Chicago, Illinois, at the Palmer House

For further information address Dr Dean M Lierle, Secy-Treas , University Hospital, Iowa City, Iowa

A CASE OF UNUSUAL CONGENITAL FISTULA OF THE AURICLE

JOHN KEOHANE M B ,

STETTLER, Alta, Canada

The detailed and informative article (Skokan) on the entire subject of congenital auricular fistulae in THE LARYNGOSCOPE of September, 1957, brings to my mind an unusual case I recently treated

My patient, a female, aged 31, had a history dating back many years She had several operations some mere incisions with drainage of recurrent infected cysts, others, more determined attempts to irradicate her annoying and painful complaint

She was not quite sure whether her trouble first started in the concha or post auricular region When I first saw her she had a sinus that extended from the post auricular region to the junction of the concha and the floor of the external auditory canal She informed me that it discharged thick pus continually, and was liable to recurrent attacks of acute inflammation with considerable pain, discomfort, etc Gentle pressure with the finger-tip over the concha caused pus to present both anteriorly and posteriorly This also caused acute pain, and the area where the sinus opened in the concha was very tender indeed This, to my mind, indicated involvement of the perichondrium and cartilage of the concha, furthermore, the conchal sinus was surrounded by an area of necrotic looking skin about 1 cm in diameter, and the post auricular area was also quite unhealthy looking and scarred from repeated surgery

The problem was to cure the disease and preserve the appearance of the auricle as much as possible I thought of injecting the sinus with radio-opaque oil, but saw little point in it

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AMERICAN BOARD OF OTOLARYNGOLOGY

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THE ABSORPTION OF TOPICALLY APPLIED TETRACAINE AND COCAINE*

JOHN ADRIANI, M D ,
and
DONOVAN CAMPBELL, M D ,
New Orleans, La

LOCAL ANESTHETICS

Local anesthetics rank high in the list of drugs which cause unnecessary deaths Those who consistently use local anesthetics are familiar with their hazards, occasional users are often less versed in their pharmacology, toxicology and technique of use and usually experience the majority of difficulties[1] The protocols of mishaps indicate that reactions and fatalities are most frequent after topical application The otolaryngologists, in our experience, presumably because they use these drugs continuously and have respect for their potency, appear to encounter fewer difficulties

The problem of reactions following the topical use of local anesthetics was of such concern that, in 1924, a commission was delegated by the American Medical Association to review the status of the then available drugs and make recommendations concerning dosage and technique of usage[2] Although the situation has improved slowly since submission of their report, preventable deaths are still frequent Seevers[3] has commented that more people die from local anesthetics than from any other group of drugs Perhaps the problem is ignored, because the deaths occur sporadically, in many areas in the hands of many users

Conflicting statements appear in the medical literature concerning absorption of local anesthetic drugs after topical application Nearly everyone assumes that they are rapidly absorbed into the blood stream and that the high blood level

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*From the Department of Anesthesia, Charity Hospital and the Department of Surgery Louisiana State University New Orleans La

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After considerable thought it was decided to attempt a radical removal of the diseased tissue with subsequent skin grafting of the defects A plan was devised to preserve the appearance of the auricle at operation

Under general anesthesia a more or less circular incision was made surrounding the diseased conchal skin The lateral part of this incision was carried laterally through the incisura intertragica, then caudally and posteriorly, and finally in a circular manner to surround the diseased post auricular region This area was about 2 cm in diameter I might add that before the incision was made the posterior sinus was injected with Methylene Blue and the dye presented in the conchal sinus The incision was deepened to expose the entire sinus tract The supero-medial part of the sinus was surrounded by necrotic cartilage, and the circular incision was deepened to excise this cartilage The entire tract was then excised with the attached upper and lower diseased skin and cartilage The exact location of the postero-inferior end of the sinus was medial to the lobule over the lower part of the lateral surface of the mastoid process The dye was a very useful guide to the depth and location of the sinus The basé of the wound was then curetted thoroughly

The area was repaired as follows

A split-thickness skin graft was cut from the medial aspect of the left thigh and used to repair the conchal and post auricular defect The incision through the incisura intertragica and the attachment of the lobule to the skin of the face was then sutured The conchal graft was made to fill its uneven bed with one-half inch vaseline gauze The posterior area was dressed with non-sticking "Telfa" The entire area was left untouched for two weeks, and removal of the dressings showed that the grafts had taken very well indeed

I have kept the patient under observation for several months, she has an execllent cosmetic result with no recurrence of any infection, and the grafts have survived exceptionally well Her auricle looks normal and its configuration was not changed in any way by the operation This is, of course, important, especially in a female patient ably lower than those obtained after a single application. Identical blood levels were obtained if the total weight applied to a given area remained constant, even though the concentration was varied from 2 to 4 per cent. This is extremely important, because it indicates that the blood level is more dependent upon total dosage than concentration. The blood level was not detectable when 6 mgm. per kilogram of tetracaine in the form of a 0.1 per cent solution was infiltrated subcutaneously over an area of the abdomen 3 x 4 cm. The slow intravenous infusion of 6 mgm. per kilogram (.001 per cent solution) over a 20 minute period, likewise, caused no detectable quantity in the blood after the injection was complete.

When the free base was precipitated and applied to the mucous membranes, the blood level curves were identical to those obtained when comparable weights of the base in aqueous solutions of the hydrochloride were used. Absorption of the hydrochloride, incorporated in a water soluble cream base, applied to mucous membranes was prompt and rapid and occurred with ease. These data indicate that the topical application of a given dose of a local anesthetic results in blood levels similar to those obtained after rapid intravenous injection. The epithelial surfaces of the pharynx, trachea, alveoli and posterior urethra provide excellent absorbing surfaces. Drugs are readily absorbed from the pulmonary alveoli because the osmotic pressure relationships in the pulmonary vascular bed are designed to prevent collection of fluid in the sacs. Volunteers inhaling nebulized 4 per cent cocaine hydrochloride immediately experienced the stimulation characteristic of this drug and felt no appreciable numbness in the upper respiratory passages.

Similar studies were carried out using cocaine. The data closely follow the pattern of absorption obtained with tetracaine. The statement is heard that 10 per cent cocaine is less toxic than more dilute solutions, such as the 4 or 5 per cent, because the vasoconstrictor effect is more intense with the more concentrated solution and absorption is retarded. In order to determine whether or not this reasoning is correct, benzocaine crystals were incorporated in a 10 per cent is the direct cause Still, blood level studies to substantiate this assumption are not available Eggleston and Hatcher[1] indicated the role of rapid absorption in causing reactions but reported no blood levels Seevers and his co-workers,[2] studying the metabolism of cocaine, injected the drug subcutaneously, intravenously and into the stomach, but did not study absorption from the pharynx, trachea, bronchi and other mucous surfaces where it is used most often clinically

We felt that blood level studies might provide a clue to the cause of the high reaction rate and undertook such a study For obvious reasons, the study was done in the laboratory on dogs Blood levels were determined after the application of tetracaine and cocaine, the two most serviceable and widely used drugs, to the mucous surfaces of the pharynx, trachea and bronchi These blood levels were compared with those obtained after rapid intravenous injection, subcutaneous infiltration and slow intravenous infusion The rapid intravenous injection of 6 mgm per kilogram of tetracaine gave levels averaging 100 mgm per ml within one to two minutes The same quantity spread over the pyriform fossae or instilled into the trachea resulted in peak levels of 30 mgm per ml The peak was attained within four to six minutes The peak blood level was not so high, nor was it attained as abruptly, as that noted after rapid intravenous injection, but was far greater as compared to blood levels resulting from infiltration There is some difference between the curves obtained after the pharyngeal and intratracheal instillations, however, it is not remarkable, and the peak levels of both curves far exceed those after subcutaneous injection or slow infusion Epinephrine added to 2 per cent tetracaine did not retard absorption significantly The blood levels did not differ remarkably from those obtained without the use of epinephrine

In one set of experiments the total dose was doubled and applied in fractions at equal intervals of one minute over an eight to ten minute period The blood level gradually attained a peak of 20 mgm per ml after ten minutes The application of the drug in fractions resulted, as one would expect, in a gradual rise in blood levels The blood levels were consider-

Tetracaine is ten times more potent than procaine on the milligram for milligram basis, thus one mgm of tetracaine should produce the same degree of blockade as 10 mgm of procaine On theoretical grounds, one would use 1/10 as much Ordinarily one gram of procaine is the maximum quantity recommended for infiltration in an adult On such a basis, it would follow that 100 mgm of tetracaine would be the maximum used for infiltration In topical anesthesia, however, this does not apply necessarily because the absorption after topical application to the mucous membranes is far more rapid than after subcutaneous injection The total quantity, therefore, should be much less than that suggested for infiltration, how much less is difficult to say

Carabelli has attained adequate anesthesia using a 0 25 per cent solution of tetracaine He suggests 20 mgm as the limit to be applied in fractional doses Rubin and Culley[6] suggest 50 mgm as the limit to be applied in fractions over a period of 15 or 20 minutes Weisel and Tarrow[7] using quantities not exceeding 40 mgm in 1000 endoscopy procedures noted 19 reactions Seven of these were convulsive, the remainder were classified as mild circulatory In the series of fatalities reported by the writers,[1] doses as high as 180 to 200 mgm had been used in some cases Obviously, these doses were excessive and presumably accounted for the difficulties Cocaine is approximately five times more toxic than procaine, thus, on theoretical grounds, the maximum amount of cocaine, at any one sitting, should not exceed 200 mgm The question as to the maximum amount of tetracaine or cocaine to be used topically is not easily answered These data on absorption seem to indicate that the dictum "use the least amount of the most dilute solution to obtain effective anesthesia as possible" should be adopted

There is a latent or lag period from the moment a drug is applied to a nerve fiber until the full effect is established This is especially true when topical anesthetics, such as cocaine and tetracaine are being employed As many as five, and often as long as ten minutes may elapse before full anesthesia is obtained Clinicians are either unaware of this latent period, or become impatient and tend to ignore it and

and a 4 per cent aqueous solution of cocaine and applied to the pyriform fossae Should cocaine produce a vasoconstriction it should retard the absorption of benzocaine Blood levels in each case were identical to those obtained when benzocaine was suspended in distilled water When benzocaine crystals suspended in water were applied to the pharynx after first spraying with 05 norepinephrine to the point of blanching, blood levels averaging 80 mgm per ml were obtained after five to nine minute intervals with a gradual decline to the zero level after 20 minutes Although these blood levels are somewhat lower than those of the control, and the peak is attained after a longer time interval, the difference is not so great that it is remarkable

It appears that neither the vasoconstrictor effect of norepinephrine or of cocaine is sufficient to suppress appreciably the absorption of benzocaine from the mucous membranes After the application of 100 mgm of cocaine as a 4 per cent solution to the pyriform fossae the blood level rose to 8-12 mgm per ml within 4 to 6 minutes and gradually receded to undetectable levels within a period of 15 minutes The same weight of cocaine as a 10 per cent aqueous solution applied to the pyriform fossae gave curves nearly identical in contour to those of 4 per cent cocaine The peak was attained within six to eight minutes, and the maximum value was 10 mgm With 4 per cent the maximum rise was within four to six minutes and rose to 8 to 12 mgm , thus, even though some cocaine causes vasoconstriction this effect is insufficient to retard absorption significantly When cocaine was combined with epinephrine nearly identical absorption curves were obtained These were not remarkably different from those obtained with 4 per cent alone

Dibucaine and tetracaine are the most potent and most toxic of the local anesthetics which possess suitable topical actions Procaine, the least toxic local anesthetic drug in current use, is devoid of topical action From the standpoint of effective topical anesthesia, one must concede that tetracaine is the most serviceable, however, one wonders whether he is justified in using it because of its toxicity The term *potency* applied to a topical anesthetic is not easily defined ly characteristic of a drug occurs Idiosyncrasy is rare Reactions characterized by hypotension, convulsions, excitement, coma, respiratory failure, etc, are not due to idiosyncrasy These are symptoms ordinarily anticipated from overdosage Idiosyncrasy is often confused with intolerance Intolerance is a quantitative response When a reaction is due to intolerance the usual response expected of the drug occurs, but with a quantity far less than the usual therapeutic dose Intolerance also is uncommon but occurs more frequently than allergy or idiosyncrasy It may be encountered in aged, poor risk subjects who are unable to metabolize the drug at the usual rate

The tendency to implicate allergy as the cause of reactions is all too prevalent Many drugs, local anesthetics included, combine with protein and become antigenic. There is a remarkable difference between symptoms caused by overdosage and by an allergic response When the response is an allergic one, eczema, urticaria, laryngeal edema or bronchospasm develop These symptoms, particularly those manifested by cutaneous lesions, require some time to develop Several hours may elapse before they appear, and they persist for several days An allergic response implies that there has been previous contact with the drug, which invariably is the case Such sensitivity may be detected by the use of patch tests or raising intradermal wheals It is possible for a fatal reaction to be anaphylactoid, but this is rare indeed A minute amount of a drug applied topically intracutaneously, or by any other route, promptly causes syncope and death The quantity ordinarily used for raising a skin wheal or for performing a conjunctival sac test may cause death Intracutaneous or conjunctival tests are of questionable value They may detect the occasional patient who has become sensitized and is truly allergic, but they are no value in detecting intolerance, likewise they are of no value in determining who may develop an anaphylactic response The quantity used to perform the test would be lethal to a truly sensitive subject

SUMMARY

Fatalities and untoward reactions occur more frequently commence surgical manipulations before anesthesia is fully established The anesthesia is usually inadequate and a second application is often made before the first has had an opportunity to exert its effect It can be seen how such a practice could lead to overdosage As a rule the longer lasting drugs manifest a longer latent period

Most physicians are generally aware of the effects of over concentration of local anesthetics on the central nervous system Local anesthetics depress cardiac tissues, the myocardium may be so depressed that asystole results This depressant effect of local anesthetics has been utilized to decrease prophylactically cardiac irritability and obviate arrhythmias during thoracic surgery Local anesthetics also cause vasodilatation Severe degrees of hypotension may result when myocardial depression and vasodilatation occur simultaneously There is no reason to assume that both the circulatory and nervous systems cannot be involved simultaneously, particularly when overwhelming doses are used, in fact, this appears to occur in reactions from tetracaine

Should a serious reaction occur, one is faced with two emergency situations, respiratory failure and asystole if cardiac arrest is suspected immediate opening of the thorax and cardiac massage is indicated, if the heart has not stopped but the blood pressure is unobtainable, vasopressors, such as ephedrine, phenylephrine (neosynephrine) or methoxamine (vasoxyl) or similar drugs should be administered intravenously Artificial respiration must be instituted immediately and maintained throughout the period of apnea or inadequate ventilation Obviously one should not undertake the administration of local anesthetics in situations in which it is not possible to institute resuscitative measures immediately In other words, one should have available apparatus for performing artificial respiration

Most reactions are due to overdosage Certain reactions, however, cannot be ascribed to overdosage, and are due to other causes Most clinicians classify reactions as due to idiosyncrasy In idiosyncrasy the usual therapeutic dose of drug gives a qualitative deviation from the anticipated pharmacological response, in other words a response not ordinari-

A TECHNICAL AID IN ADENOIDECTOMY*

G. OBREGON, M.D.,

Iowa City, Ia.

A great deal has been written in relation to the surgical technique of the adenoidectomy, and it is generally agreed that direct visualization of the nasopharynx is highly desirable.[1,2,3,4,5,6,7,8,9,10]

Adenoidectomy on one hand has been greatly facilitated with the development and wide acceptance of the self-retaining type of mouth gags and the use of the head-low position. The surgeon does not require assistants, and aspiration pneumonia has been reduced to a minimum. On the other hand the use of the self-retaining mouth gag and the head-low position have contributed to a poorer exposure of the nasopharynx, often resulting in incomplete adenoidectomy.

Several authors[1,7] have advocated the sitting position in preference to the head-low position for the performance of adenoidectomy. The entrance of blood into the tracheobronchial tree in this position is prevented by an endotracheal tube with an inflated cuff. The soft palate is displaced with the use of one of the different types of palate retractors available. Two assistants are required: one to move the head of the patient into different positions, and the other to keep the operative field clean by the use of suction.[1]

The dangers inherent in the sitting position under general anesthesia, we believe, have been minimized by its advocates when they state[7] that the only advantage of the head-low position is the prevention of the entrance of blood into the trachea. In other surgical fields in which the sitting position is frequently used, numerous devices have been introduced to prevent orthostatic hypotension.

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*Department of Otolaryngology and Maxillofacial Surgery, University Hospitals, Iowa City, Ia.

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when local anesthetics are applied topically than when injected It has been assumed that rapid absorption is the cause, but direct evidence in support of this contention is scarce The writers have determined the blood levels of tetracaine and cocaine, in dogs, after the *1* topical application in the pyriform fossae, *2* trachea and bronchi, *3* after the rapid intravenous injection, *4* after the slow intravenous infusion, and *5* after infiltration into subcutaneous tissues

The quantity of drug which results in no detectable blood level when infiltrated subcutaneously gives levels, when applied topically, equal to one-third to one-half of those noted after rapid intravenous injection Epinephrine did not retard the absorption of either drug Four per cent cocaine and 10 per cent cocaine gave similar blood levels The basic form was as rapidly absorbed as the solution of the salt

The absorption from mucous membranes is far more rapid than clinicians have realized and closely simulates slow intravenous injection

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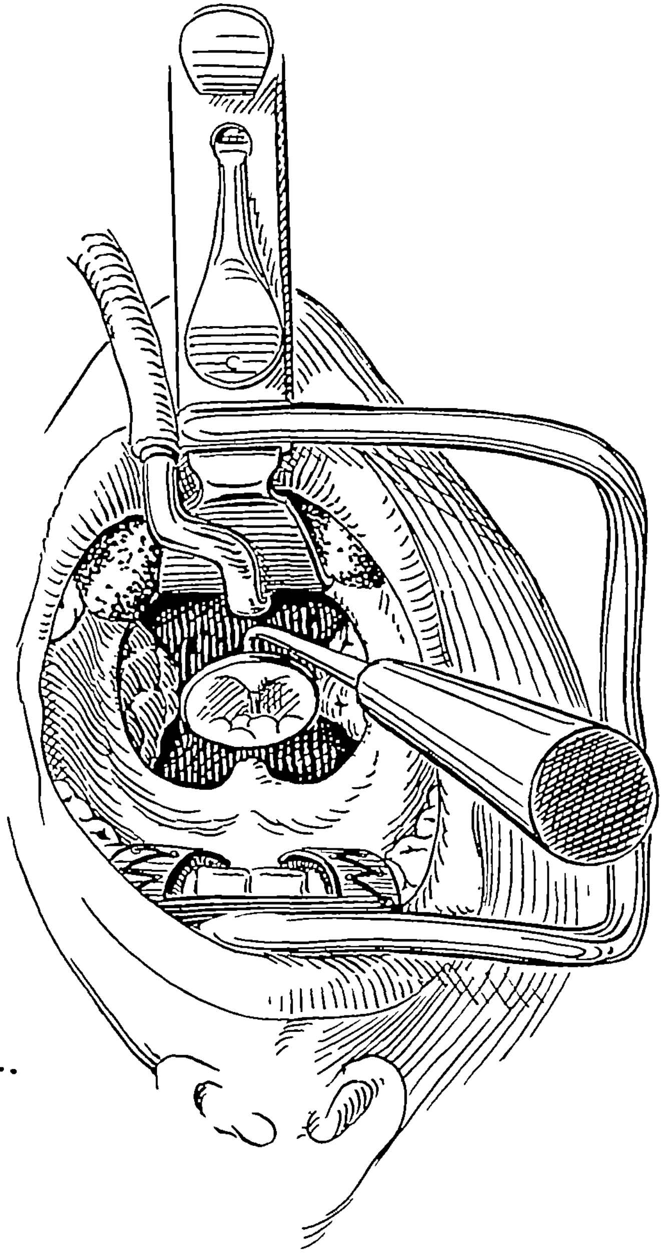


1.

Fig 1 A laryngeal mirror previously warmed in hot saline is placed in the oropharynx of the patient for indirect visualization of the nasopharynx.

It is well-known that passive tilt to the sitting position can be followed by hypotension even in normal subjects If the compensatory reflexes are impaired by the commonly used pre-anesthetic medications the postural hypotension is greatly increased[12] The hypotension may be followed by cerebro-vascular accidents We believe that this technique has definite advantages, but should not be used routinely because of the inherent dangers In cases of secondary adenoidectomies when there is a great deal of tension of the soft palate as a result of scarring, the erect position may be the procedure of choice and the only way in which a complete adenoidectomy can be performed

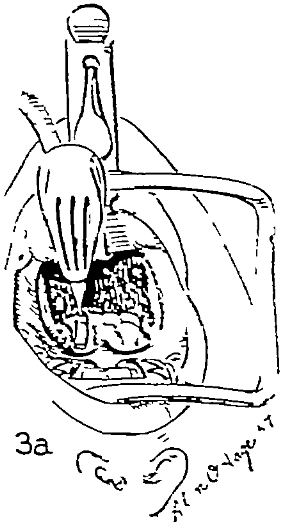
If an adenoidectomy is to be performed under direct visualization the self-retaining type of mouth gags should not be employed since they produce tension of the soft palate This makes exposure of the nasopharynx extremely difficult, and under these circumstances if the operator uses a palate retractor, lacerations of the soft palate will frequently occur

In our primary adenotonsillectomy we routinely use a self-retaining mouth gag and the head-low position A No 4 laryngeal mirror (see Fig 1) that has been previously immersed in a glass containing warm saline is placed in the oropharynx of the patient for indirect visualization of the nasopharynx

For the removal of lymphoid tissue from the nasopharynx various instruments can be used according to the needs of the individual case We prefer the Barnhill and Jones curettes,[11] the cutting edges of which should be kept sharp at all times The Meltzer punch forceps are especially useful for the removal of smaller collections of lymphoid tissue in the fossae of Rosenmueller The shanks of these instruments help in the retraction of the soft palate With one hand the laryngeal mirror is manipulated and with the other the cutting instrument

The main mass of midline adenoid tissue is removed with the first two or three strokes of the curettes The nasopharynx is kept free of blood with the Yankauer suction tube If bleeding interferes with further work in the nasopharynx by direct method[2] Because of the inverted image obtained the surgeon tends at first to make motions in reverse, but after the first few cases this initial difficulty is easily overcome

Caution should be taken when removing lymphoid tissue from the fossae of Rosenmueller with a curette or sharp dissection The mucosa of the medial side of the Eustachian tube should be left undisturbed otherwise adhesions will result from the healing of two opposite raw areas[9] (see Figs 3a and 3b)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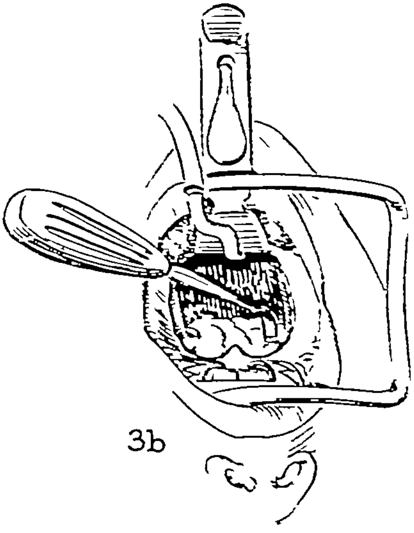
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Fig 3a The correct position of the curette is illustrated The shank of the instrument is placed vertically avoiding the Eustachian tube

Fig 3b The curette is improperly placed If it is placed obliquely the posterior aspect of the Eustachian tube may be lacerated

A review of the literature showed that one author[13] had described the technique we have advocated A recent publication[14] also outlines a similar procedure The writer emphasizes the removal of the highest portion of the adenoids located immediately posterior to the choanae with a Takahashi forceps introduced through the nose and visualized with the laryngeal mirror placed in the oropharynx We have also practiced this procedure on several occasions, with satisfactory results

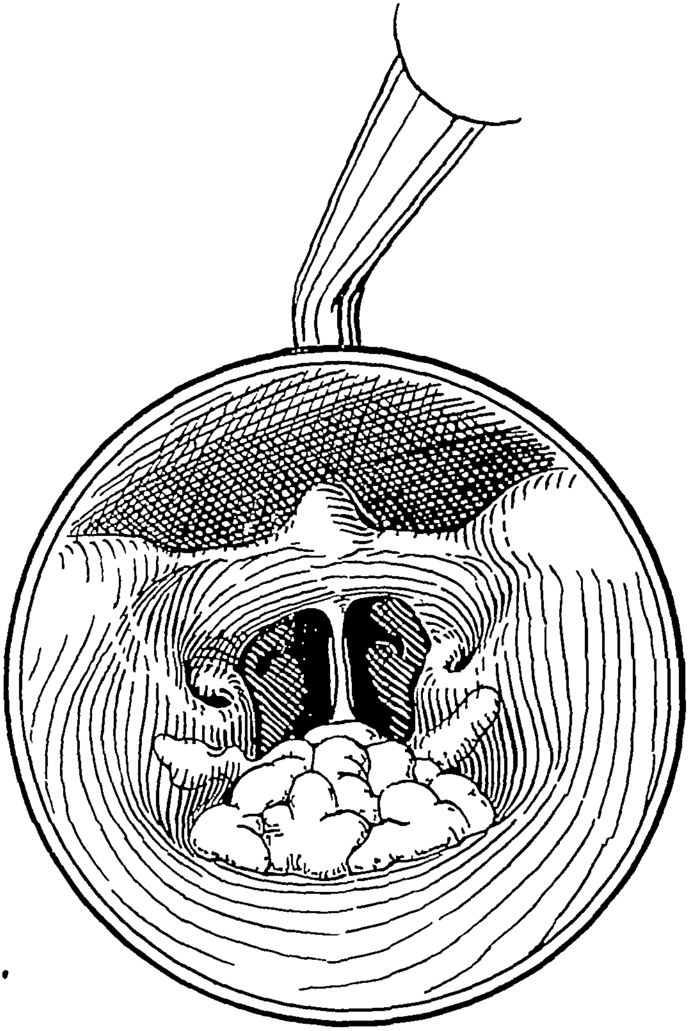

Fig 2 Drawing of the nasopharynx as seen in the laryngeal mirror The soft palate is not shown in these figures

a post nasal pack is inserted, and the tonsillectomy is performed After its completion, attention once more may be directed to the nasopharynx, and any remnants of lymphoid tissue removed with the Meltzer punch forceps

We have been using this technique for the past five years with very gratifying results The view obtained by the indirect method (see Fig 2) is inverted from that obtained

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OTOLARYNGIC RADIOLOGY COURSE

The Departments of Radiology and Otolaryngology, College of Medicine, the Ohio State University, will offer a postgraduate course in otolaryngic radiology February 4 and 5, 1958, at University Hospital, the Ohio State University Health Center, Columbus, Ohio, under the direction of John F Holt, M D , Professor of Radiology, University of Michigan, Lewis Etter, M D , Professor of Radiology, University of Pittsburgh, Roderick Tondreau, M D , Professor of Radiology, University of Pennsylvania, Sidney Nelson, M D , Professor of Radiology, the Ohio State University

There will be lecture periods with time given for group discussion Dr Holt will discuss the esophagus, salivary glands, tracheo-bronchial tree, and skull proper Dr Etter will discuss the paranasal sinuses, nose and nasopharynx Dr Tondreau will discuss the mastoid and larynx

Registrants are encouraged to bring interesting roentgenograms for participation in discussion periods

A fee of $35 00 must accompany the registration application Luncheon for the two days will be included in this fee All registrations are to be completed by January 15, 1958

Address applications or requests for additional information to William H Saunders, M D , Department of Otolaryngology, University Hospital, Columbus 10, Ohio

The adenoidectomy should not be performed blindly or by palpation These methods should be delegated to the historical background of the operation, but its use in modern surgery should be condemned

SUMMARY

1 The sitting position should not be used routinely in the performance of the adenoidectomy because of orthostatic hypotension and possibly cerebro-vascular accidents

2 A technique of indirect visualization of the nasopharynx is described

3 This technique has been used in the past five years with encouraging results

4 Blind methods in the performance of the adenoidectomy are condemned

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SUBCOMMITTEE ON HEARING IN CHILDREN

The American Academy of Ophthalmology and Otolaryngology, through its Subcommittee on Hearing in Children of the Committee on Conservation of Hearing, has been conducting a long-term nationwide study of problems relating to the conservation of hearing in children The specific aims are to develop the most efficient case-finding methods and to use these methods in estimating the magnitude of the problem in the country, to study state laws and review current practices and facilities for rehabilitation of hearing impaired children, to help develop methods for medical and surgical rehabilitation standards, and ultimately to use the Subcommittee findings in assisting professional workers to improve and enhance programs in hearing loss

In the second year of operations, a full-time Executive Director has been engaged, and offices established at the Graduate School of Public Health, University of Pittsburgh An initial study is being conducted in Pittsburgh to identify early medical signs and symptoms which may indicate danger of hearing impairment, to measure the psychological, social and other effects of such impairment and to develop efficient and economical methods for the testing of hearing in children The Pittsburgh study is a cooperative effort among the following The Subcommittee on Hearing in Children, the Graduate School of Public Health and the School of Medicine of the University of Pittsburgh, the Pittsburgh Board of Public Education, and the Allegheny County Department of Health

The members of the Subcommittee on Hearing in Children are Dr John E Bordley, Baltimore, Dr Victor Goodhill, Los Angeles, Dr Hollie E McHugh, Montreal, Dr S Richard Silverman, St Louis, and Dr Raymond E Jordan, (Chairman) Pittsburgh An advisory committee of consultants from the University of Pittsburgh includes Dr Samuel M Wishik, Dr Leo G Doerfler, and Dr Isidore Altman Grants from the United States Children's Bureau through the Pennsylvania Department of Health and from the National Institutes of Health are providing financial support

BOOK REVIEWS

Sprachaudiometrie Grundlagen und Praktische Anwendung Einer Sprachaudiometrie fur das Deutsche Sprachgebiet Doz Dr Med Karl Heinz Hahlbrock Georg Thieme Verlag Stuttgart (in the U S A. and Canada Intercontinental Medical Book Corporation, New York 16 N Y 1957 Soft cover 182 pp $5 00

Dr Hahlbrock has produced a comprehensive systhesis of the principles and practices relating to speech audiometry The chapters include the development of speech audiometry, the practical procedures interpretation of test results, comparisons between classical tests of hearing and speech audiometry and the techniques of application of speech audiometry to the selection of patients for surgery and the selection of hearing aids

For those who can understand the German language this should be a useful guide to speech audiometry There is a short introduction by Prof Dr F Zollner

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Educational Guidance and the Deaf Child Edited by A W G Ewing The Volta Bureau 1537 35th St N W, Washington 7, D C 1957 345 pp

A W G Ewing Professor and Director of the Department of Education of the Deaf University of Manchester, has brought together a collection of studies that reflect the activity in the Department of Education of the Deaf at his University The major portions of the volume deal with infancy and early childhood and children of school age A good deal of emphasis is placed on screening tests and guidance for parents and on tests of abilities and attainments The book is a useful compendium for those who want to acquaint themselves with the forward looking activities at Manchester

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Look, Listen and Lipread Edited by Betty C Wright The Volta Bureau, 1537 35th St N W Washington 7, D C 1957 Soft cover 110 pp

Miss Wright, who is listed as Consultant American Hearing Society and U S Office of Vocational Rehabilitation, Instructor of Lipreading Hearing Center, Medical College of Virginia has gathered together contributions from experienced teachers of lipreading that the latter have found useful in practice The compendium is a useful source of tried material for the teacher of lipreading

S R S

THE 11TH CONGRESS OF THE INTERNATIONAL ASSOCIATION OF LOGOPEDICS AND PHONIATRICS

The 11th Congress of the International Association of Logopedics and Phoniatrics will take place in London, August 17-22, 1959 The following official reports will be presented The Inheritance of Voice and Speech Disorders, Prof R Luchsinger, M D, Zurich, Defects of Articulation, Muriel Morley, B Sc, F C S T, Newcastle, The Physiology and Pathology of the Soft Palate, Prof Lucio Croatto, M D, Padua The official languages of the Conference will be English, French, and German

Those working in the field of Speech and Voice Therapy and all who are interested in this specialty are invited to attend and to submit papers

If intending to be present, whether submitting a paper or not, please inform the Congress Secretary at the earliest possible date

Papers are invited on subjects relevant to the three main reports or any other aspect of speech and voice Only one contribution will be accepted from any one member of the Congress and this must not have been previously published The Committee reserves the right to select papers Papers should be restricted to 15 minutes in length, demonstrations to 10 minutes In special cases 20 minutes may be allowed for a paper of great importance but only if application is made at the time of submitting the title Should a group of four or more people wish to present a symposium or a prepared discussion on a theme, consideration will be given to allocating up to one hour for such a contribution

Titles must be received by September, 1958 Summaries must be received not later than November 15th, 1958

All communications are to be sent to Peggy Carter, L C S T, 46 Canonbury Square, London, N 1

THE INTERNATIONAL CONGRESS ON THE EDUCATIONAL TREATMENT OF DEAFNESS

The University of Manchester Department of Education of the Deaf, will sponsor The International Congress on the Educational Treatment of Deafness, July 15-23, 1958

The Minister of Education for England and Wales has decided to recognize the Congress as a Short Course which teachers of the deaf may attend under Grant Regulations

An interesting program has been arranged

Demonstrations will be given to illustrate some aspects of the research that is in progress in the audiology unit and audiological laboratories of the Department of Education of the Deaf, and in collaboration with the Department of Otolaryngology, the Public Health Department and School Medical Service of the City of Manchester, and the Ear, Nose and Throat Department of the Royal Manchester Children's Hospital The subjects of the demonstrations will include procedures for the making of screening tests and assessments of the hearing of babies and young children, the results of guidance to parents to enable them to give home training to their children of pre-school age whose hearing is impaired, and the results of an experimental investigation on problems in architectural acoustics that concern the use of hearing aids in school buildings

Arrangements are being made to offer accommodation to members of the Congress in University Halls of Residence The cost of this type of accommodation is expected to be about £1 2s od per day, including bed, breakfast and dinner The University refectory will be available for meals during each day

For those members who wish to do so, arrangements will be made to visit audiology clinics and special schools in London, Oxford and other places In connection with the Congress it is hoped to organize tours to places of interest The dates proposed for this are July 9th, 10th, and 11th

For further details write Prof A W G Ewing, Department of Education of the Deaf, The University, Manchester 13, England

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Place The Homestead, Hot Springs Va 1959

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THE
LARYNGOSCOPE.

VOL. LXVIII FEBRUARY, 1958 No. 2

FIXATION OF FRACTURES IN THE MIDDLE THIRD OF THE FACE, WITH KIRSCHNER WIRES.*†

HERBERT H. HARRIS, M.D.,
Houston, Tex.

There is an ever increasing number of fractures about the body as a result of violence, most of which are caused by traffic accidents. Many of these are about the head and face, and not infrequently of the middle third. Though fractures in the middle third of the face may be the only or principal injury, they do occur with other fractures, such as the mandible or long bones of the body, and many times with severe skull or brain injury.

When fractures of the middle third of the face do occur with other injuries the picture is more complicated, and the other injuries may be of primary concern. It is because of these severe injuries that facial fractures may either go unnoticed or ignored until late, enough so at times to make their primary reduction impossible.

There are many things which must be taken into consideration before a fracture in the middle third of the face is reduced. Severe or critical injury elsewhere may prevent the early reduction of these fractures; in fact, unless I can get them rather early, four or five or even ten days' delay seems to make little difference in the reduction, and with the use of antibiotics infection is no longer a hazard. Even at the end

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†From the Department of Otolaryngology, Baylor University College of Medicine.

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about the lacrimal bone and the lacrimal duct may cause tearing of the eye

The diagnosis of facial fractures is usually not difficult for one who is familiar with the landmarks Tactile sense of the trained index and middle fingers can always elicit deformity regardless of the swelling, unless infection has taken place and the tissues have become brawny As mentioned before, palpation of the nasal bones, the infraorbital ridge, the malar eminence of the zygomatic bones and the occlusion of the teeth are the points which, if in their proper position, almost always means either no fracture or displacement of the fractured bones

There are many positions for taking X-ray to determine the extent and location of fractures in this area, but due to the thinness of some of the bones and shadows cast by overlying bone I have never been satisfied with flat plates Usually, and I might say always, a good stereo in the Waters position studied thoroughly will give not only a clear picture of the nature and extent, but also will tell one the direction of the force which caused the fracture This is always very important to me, as a force for traction in the opposite direction to that causing the injury must be exerted to reduce the fracture

There are many methods of reducing fractures of the zygoma, as there are many methods used to fix other fractures I do not believe that one can use any one method for all facial fractures any more than one method only can be used for fixing fractures of long bones Open reduction and wiring of the fragments has its advantages as well as its disadvantages Packing a sinus to reduce a fracture of the infraorbital ridge and anterior wall of a sinus, when the zygomatic bone has been fractured and pushed into the sinus, is not always enough to insure good results The use of the Kirschner wire as a method of fixation is not the method I use in every case, but I do believe that it is the simplest and the most satisfactory when combined with other methods if necessary

The Kirschner wire (see Fig 1a) much like the Steinman of four weeks I have been able to reduce some of these fractures, for they heal by scar tissue, and at this time one can reduce them with some difficulty, mobilize the fragments for better alignment, but when there are small comminuted areas it is most difficult to replace these small fragments

The primary objective when a patient has these, combined with other severe injuries, is to preserve the life of the patient, since in themselves these fractures are rarely serious Shock, severe brain damage, chest and abdominal injuries must be treated first Hemorrhage from the broken blood vessels along the line of fracture is one complication which must be controlled early, regardless of the severity of injuries elsewhere Most bleeding can be controlled by packing the nose when such fractures extend through the nasal cavities, although other means must be resorted to when necessary

Airway obstruction may follow some severe injuries and a tracheotomy should be done without hesitation When lacerations of the face do occur in combination with these fractures they should be meticulously repaired early, even if it is impossible to reduce the fractures at the same time If the fracture is to be reduced within the first 24 hours, I recommend that the fracture be reduced first and the laceration repaired last, for sometimes in manipulation, the lacerated areas may be separated, and a good cosmetic result cannot be obtained

There are several anatomical landmarks which must be kept in mind as a guide to obtain the best result, the nasal bones, the infraorbital ridge, the malar eminence of the zygomatic bone and the occlusion of the teeth Of course, all of these may not be involved in every fracture, but they all must be restored to the original position if good function and good cosmetic results are obtained Even though the alveolar ridge with the upper teeth may not be involved fractures of the zygoma, the infraorbital ridge and the floor of the orbit may allow the eye to dip so that diplopia develops and even trismus due to the impingement of the coronoid process on the zygoma Fractures of the nasal bones, with displacement, may cause nasal obstruction and fractures pin but smaller comes in three sizes, 062, 045, and 035 of an inch, is made of stainless steel and can be drilled into the bone or through the bone without first making an opening Ipsen[3] described the use of the Kirschner wire in fixing fractures of the mandible in 1933 Brown, et al,[1,2] reported its use first in 1951 for fractures in the middle third of the face There is one important point to remember in using the wire. If a drill especially made for the Kirschner wire is not available, any hollow shaft drill can be used, but only about one-and-one-half to two inches of the wire should be allowed to extend beyond the end of the chuck (see Fig 1b) Allowing such a small amount of the wire to extend beyond the chuck prevents wobbling of the wire, and the direction of the drilled wire is more accurate In most facial fractures I have found the 062 or the heavy Kirschner wire to be the most satisfactory size

Though fractures may occur with much comminution, there are several which I believe rather completely typify most of these fractures of the middle third of the face Probably the most common injury is that to the nose and the frontal processes of the maxilla I shall not take this up in my discussion except insofar as it is related to other fractures in this region

Though no two fractures are alike, most are similar in that they may be classified into six general types

1 Simple zygomatic fractures

2 Zygomatic fractures with comminution of the infraorbital ridge and anterior wall of the sinus

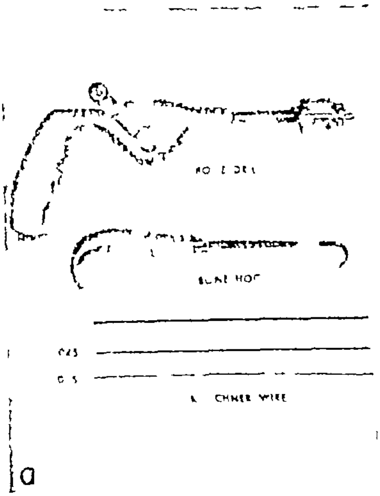
3 Transverse fractures of the maxillae or LeFort I

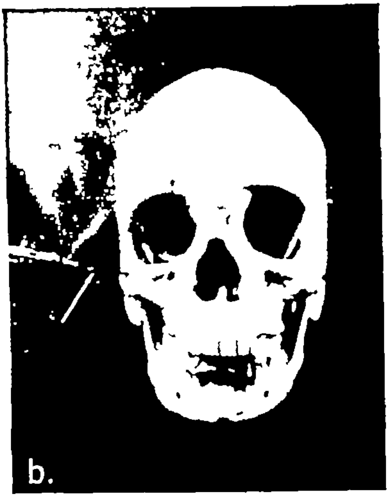
4 Pyramidal fractures of the maxillae or LeFort II

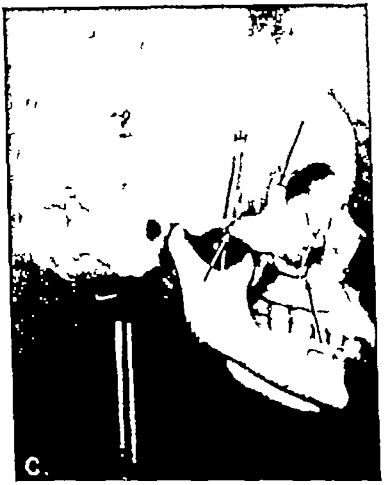
5 Cranio-facial fractures of LeFort III

6 Combination of some of the above with comminutions

Simple zygomatic fractures not infrequently may be reduced with the bone hook or some other device such as a towel clip, though occasionally I have been unable to reduce the fracture without entering the maxillary sinus when there







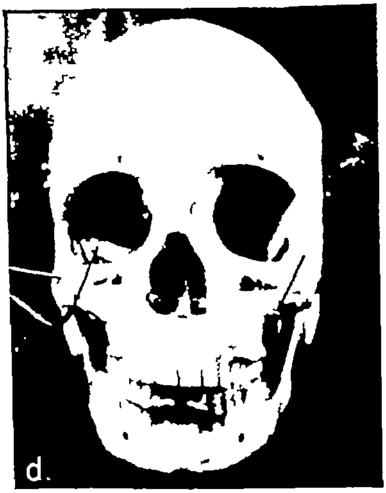
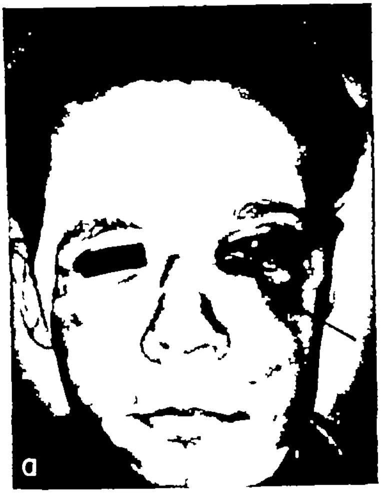


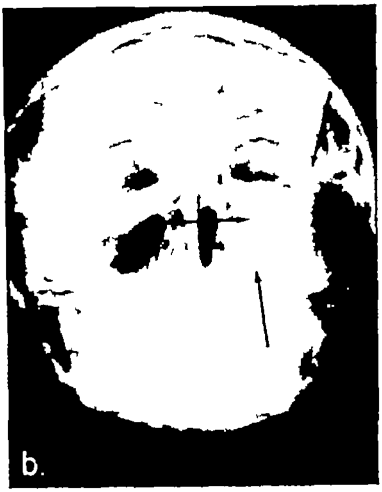
Fig 1a Ordinary bone drill bone hook and the three sizes of Kirschner wires

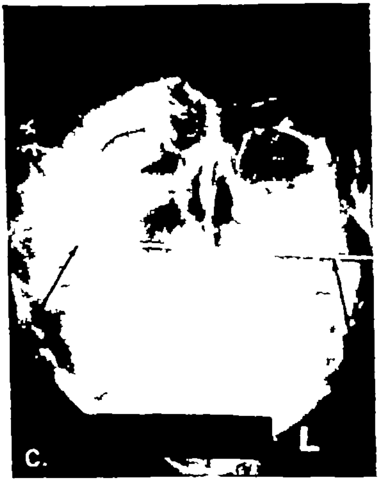
Fig 1b Only about 1½ to 2 inches of the wire are allowed to remain between the bone and the chuck of the drill to prevent wobbling

Fig 1c Fracture lines in simple zygomatic fracture

Fig 1d Shows the position of the bone hook to reduce a typical zygomatic fracture and the direction of the Kirschner wire into the other side







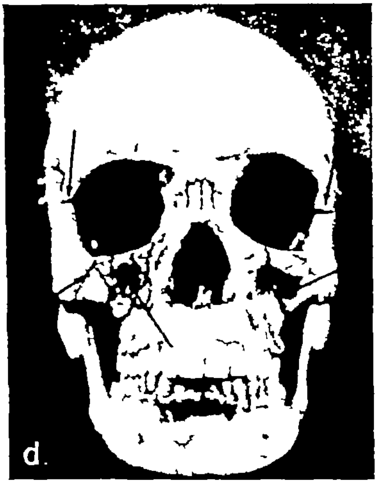


Fig 2a Typical depression over the cheek area in simple zygomatic fracture

Fig 2b Typical fracture lines Note the reduced size of the maxillary sinus due to the depressed zygoma.

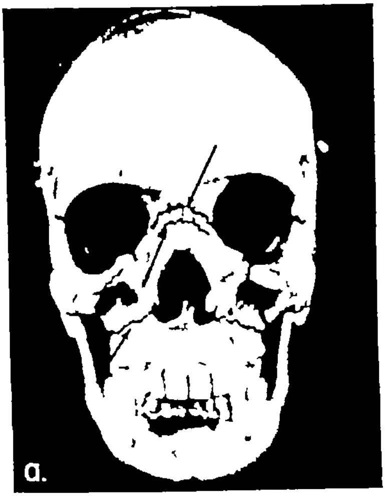
Fig 2c. Reduced fracture fixed with a Kirschner wire by fixing across to opposite zygoma.

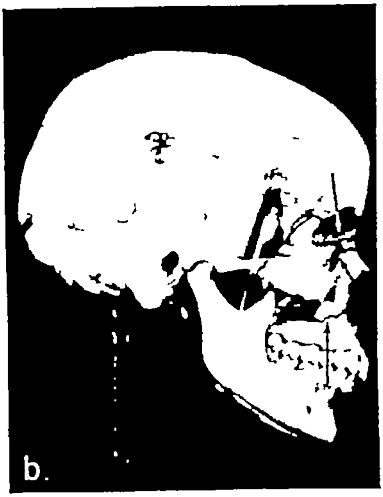
Fig 2d Right zygoma shows typical fracture lines with comminution of the infraorbital margin and anterior maxillary wall through the zygomatic arch and the frontal-sphenoid suture line area. Left zygoma shows typical fracture lines of the simple zygomatic fracture

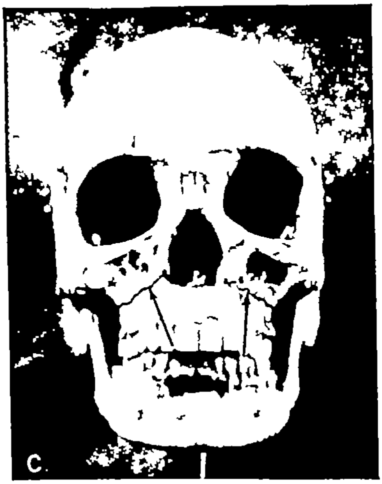
seemed to be impaction of the fragments I have not found it necessary to make an incision above the arch The fracture lines in a simple zygomatic fracture (see Fig 1c) usually occur in or near the suture line of the fronto-sphenoidal process with the corresponding bones, near the suture line in the zygomatic arch and through the anterior wall of the maxillary through the infraorbital foramen downward and laterally through the thin lateral wall of the maxilla

A large percentage of these simple fractures when reduced will remain in good position without fixation This depends materially on how much comminution there is at the fracture line If the zygomatic bone does not remain in good position, it can be held in place with the bone hook and a 062 Kirschner wire drilled through the body of the fractured zygoma into the medial maxillary wall across the nose, through the medial wall and into the lateral wall of the opposite maxillary just below the body of the zygoma (see Fig 1d) Formerly, I tried to drill the wire through to the opposite body of the zygoma, but this is not necessary as it does keep the wire away from the opposite orbit and the infraorbital nerve I have never seen an accident occur with the wire, but I am sure it would be possible for the wire to be deflected into the opposite orbit if one were not very careful when trying to fix the wire into the opposite body of the zygoma Passing through these several structures, the medial wall of both maxillary sinuses, the nasal septum and into the lateral wall of the opposite sinus, usually give sufficient support of the wire If a satisfactory reduction and fixation is not accomplished at first the wire may be withdrawn In difficult cases I have drilled it across to the opposite side as many as three or four times before getting a satisfactory position I have never seen any untoward results as it punctures the turbinate and is withdrawn There may be some bleeding which stops very quickly A case of simple fracture of the zygoma is herewith illustrated (see Figs 2a, 2b, 2c and 2d)

Comminuted fractures of the infraorbital margin and the anterior wall of the maxillary sinus, combined with a depression of the zygomatic bone into the sinus, poses a slightly greater problem in obtaining good results (see Figs 2d, 3a







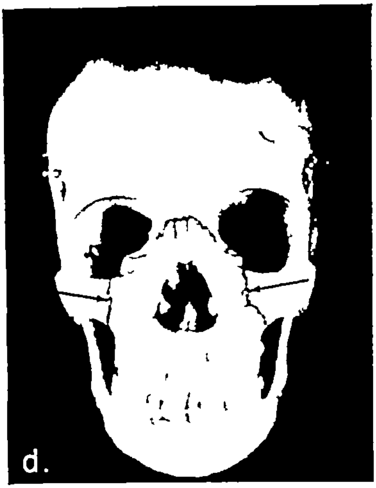


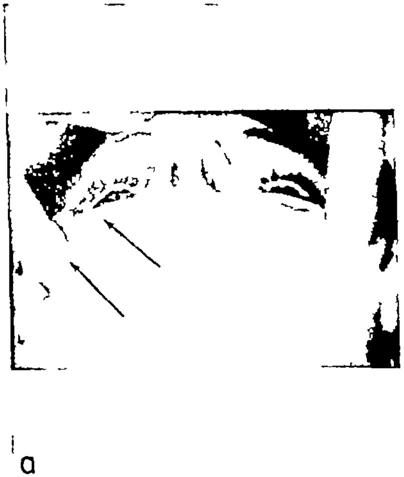
Fig 4a Typical lines of fracture transverse pyramidal and craniofacial from below upward Front view

Fig 4b Same Side view

Fig 4c Fracture lines transverse fracture of maxillae

Fig 4d Fracture lines pyramidal fracture of maxillae

and 3b) Entering the maxillary through the canine fossa region and making a counter opening into the inferior meatus for the purpose of removing the gauze packing is usually necessary I pack the sinus with one-half inch gauze impregnated with aureomycin ointment and replace and mold the comminuted fragments back into place, and suture the wound, bringing the gauze out of the opening in the inferior meatus



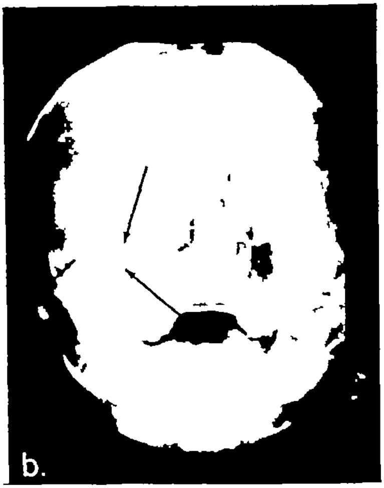
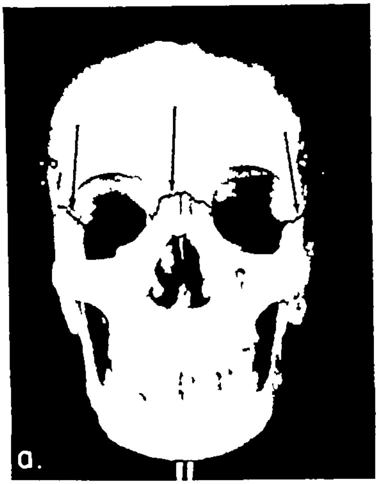


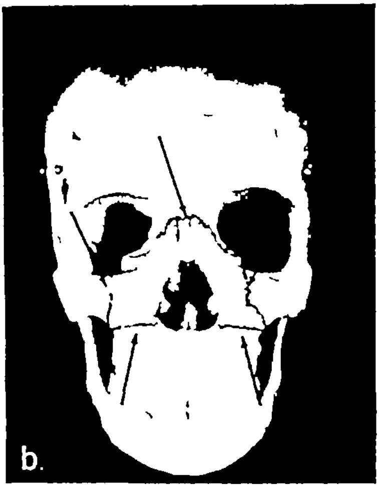
Fig 3a Typical appearance of the face in a fracture of the zygoma with comminution of the anterior wall of the sinus and the infraorbital margin

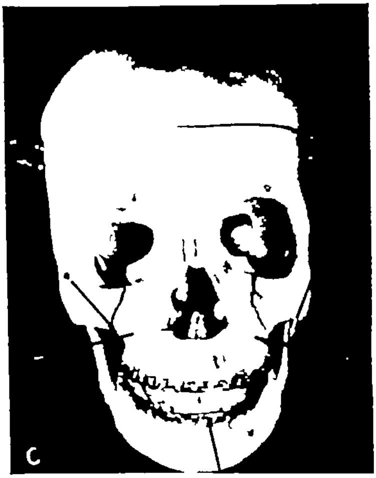
Fig 3b X-ray findings of the same patient showing the comminutions when stereo was viewed

The body of the zygoma, which usually is not comminuted, may be held in place as in a simple zygomatic fracture, passing the wire across the gauze filled cavity Of course, the gauze must be left in as long as the wire, which I find is usually 18 to 21 days

I wish now to take up the group of fractures known as the LeFort I, II and III, or the transverse, pyramidal and craniofacial features (see Figs 4a, 4b,) These have one factor in common The maxillae containing the teeth is fractured from the skull at different levels The teeth, therefore, do not occlude normally or properly Though the maxillae are







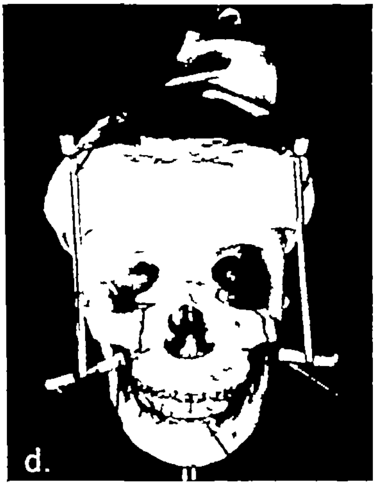


Fig 5a Fracture lines in cranio-facial fracture

Fig 5b Fracture lines in transverse and pyramidal fractures from below upward

Fig 5c. Pyramidal fracture of maxillae using Kirschner wires for cross wiring and direct fixation into opposite zygoma Fracture splints on teeth

Fig 5d Pyramidal fracture with wires withdrawn from opposite zygoma into maxillary sinus so that traction can be applied to head cap Fracture splints on teeth.

usually fractured downward and backward, occasionally the maxillae are pushed backward and upward

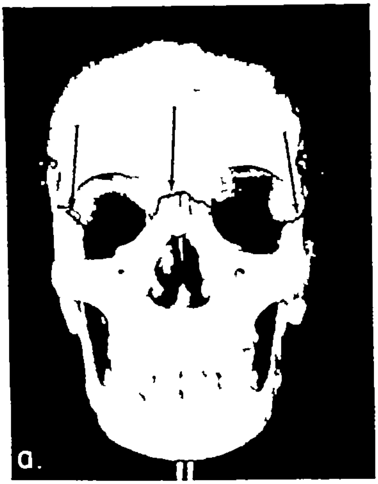
The transverse fracture occurs just above the alveolar margin so that the teeth, if they are present, are contained in the lower fragment (see Fig 4c) In my experience these are less common than the pyramidal, but likely occur when dentures are worn and the blow occurs over the dentures, causing a shearing injury

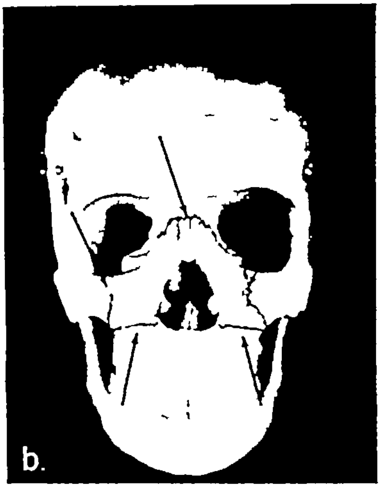
Pyramidal fractures occur a little higher up on the maxillae involving the nasal bones, the anterior wall of the maxillae and the infraorbital ridges, the floor of the orbit and the anterior and lateral wall of the maxillae, usually at different levels on each side (see Fig 4d)

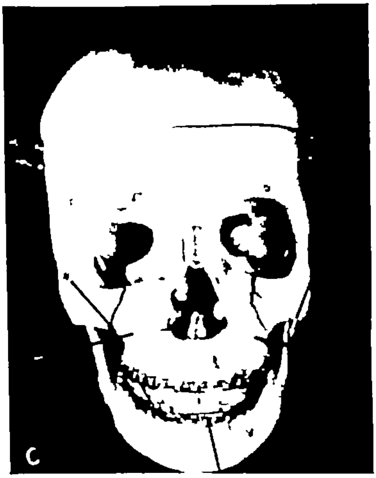
The cranio-facial fracture is at a still higher level through the ethmoid labyrinth into the posterior part of the inferior orbital fissure, near the suture line between the fronto-sphenoidal process with the corresponding bones and through the zygomatic arch (see Fig 5a) To secure and maintain proper occlusion of the teeth is one main objective If no teeth are present occlusion is not so important, but maintaining good position of the fragments is essential It must be remembered that a good cosmetic result can be obtained without perfect occlusion of the teeth, but good function requires perfect occlusion

In all of these fractures the airway may be of concern and a tracheotomy may be necessary immediately, or may be necessary when fracture splints or arch bars are applied to the teeth and the nose packed to reduce a fracture

Transverse and pyramidal fractures (see Fig 5b) may be treated by cross wiring the lower fragment into the body of the opposite zygoma, especially if no teeth are present (see Fig 5c) In pyramidal fractures, if most of the teeth are remaining and the nose fractured, I do a tracheotomy, then apply the fracture splints to the teeth and reduce the fracture and try to get good occlusion by cross wiring the lower fragment into the body of the zygoma, then finally and lastly reduce the nasal fracture In most cases I have found that the lower fragment is stable, but the occlusion is not perfect and I resort to







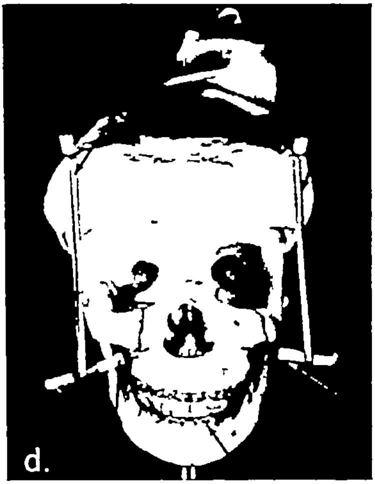


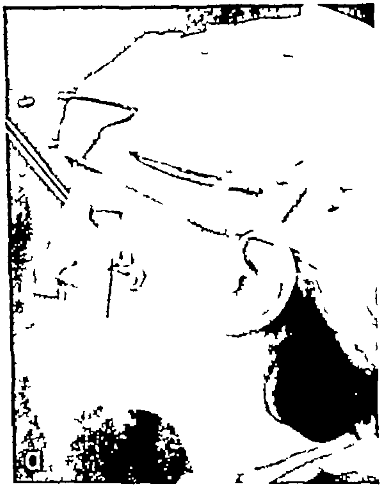
Fig 5a Fracture lines in cranio-facial fracture

Fig 5b Fracture lines in transverse and pyramidal fractures from below upward

Fig 5c Pyramidal fracture of maxillae using Kirschner wires for cross wiring and direct fixation into opposite zygoma Fracture splints on teeth

Fig 5d Pyramidal fracture with wires withdrawn from opposite zygoma into maxillary sinus so that traction can be applied to head cap Fracture splints on teeth

the head cap and traction with rubber bands after these wires have been withdrawn from the body of the zygoma (see Fig 5d) The traction is usually forward and upward as is shown in Fig 6a Sometimes when the fragment is pushed upward traction must be applied downward and forward Though flat plate X-rays show the fracture lines (see Fig 6b) a stereo in the Waters position gives much more detail The nasal



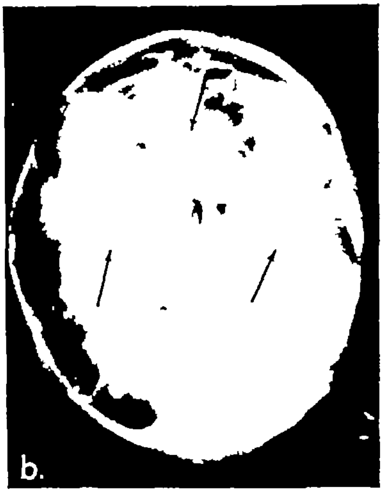


Fig 6a Pyramidal fracture with forward and upward pull of lower fragment

Fig 6b X-ray view Waters position showing typical pyramidal fracture

bones, when badly comminuted, should not be reduced until the maxillae are in good position, and then may be moulded into position a few days later if a good position is not secured at first I have found it very difficult to use one pin across the lower fragment, as not infrequently it will be deflected into the fracture line of the opposite side and no traction can be obtained on that side

Management of the cranio-facial or LeFort III type of fracture can be handled very much the same way as the transverse and pyramidal fracture, except that direct fixation cannot be done satisfactorily, due to the fact there is no adequately strong structure into which the wire may be secured It is then usually necessary, if open reduction is not done, to use the traction method, as well as fracture splints to the teeth

The use of head caps is certainly not the most satisfactory method of applying traction, but I have found none better Braiding the hair and then applying one of the "spray nets" to stiffen the hair helps some In my experience the mobile type of fixation with traction is worth the effort, because all of these patients get a good occlusion

CONCLUSIONS

1 Use of the Kirschner wire for direct fixation of fractures of the middle third of the face has been found to be very satisfactory

2 Less time is required to fix fractures by this method than by open reduction

3 Use of the Kirschner wire to which traction can be applied is most satisfactory and there is minimum scarring at the entrance through the skin

4 The use of two Kirschner wires crossing into the body of each zygoma has been found more satisfactory than trying to cross directly from one zygoma to the other in fixation of pyramidal fractures and gives the added factor that the point can be withdrawn into each maxillary and traction applied with a head cap, if the reduction has not been satisfactory

5 Where fracture splints to the teeth must be applied and the nose packed for reduction of an accompanying fracture, tracheotomy is advisable, preferably through a transverse incision

6 No accidents or infections have been encountered thus far in my cases

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ELECTROMYOGRAPHIC STUDY ON RESPIRATORY MOVEMENTS OF THE INTRINSIC LARYNGEAL MUSCLES[*][†]

FUMIO NAKAMURA, M D ,
YUTAKA UYEDA, M D ,
YUTAKA SONODA, M D ,

Kyoto, Japan

It is well known that the larynx is employed in numerous ways, and that numerous factors are involved in its neurogenic controls The behavior of the intrinsic laryngeal muscles under various functions must be dependent upon the central mechanism, of which, however, little is known If the centers causing the laryngeal movements were different it is probable that a different pattern of activity would take place This study was undertaken to differentiate the motor pattern displayed in the laryngeal muscles under various actions by recording the discharge of the individual motor unit

In the present experiments only the respiratory activity is considered The respiratory movements of the vocal cords in man were investigated by Pressman,[10] by recording a slow motion picture He showed that basically the glottis widened during inspiration and narrowed during expiration These movements are so slight in certain persons during quiet respiration as to be almost imperceptible, while, in dyspneic breathing, they increase in excursion so that the lateral movement of the cords during inspiration becomes progressively wider as inspiration becomes deeper and more forceful By recording the smoked drum tracings, Negus[9] showed that the widening of the glottis preceded a contraction of the diaphragm, and narrowing occurred just before the beginning of

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[*] This paper was read before the International Voice Conference at Chicago Ill May 20-22 1957

[†] From the Department of Otolaryngology Kyoto Prefectural Medical Colledge Kyoto Japan

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expiration Recently an investigation on impulse activity of the recurrent nerve and electromyographic recording of activity in the intrinsic laryngeal muscles was reported by Green and Neil,[8] showing that the abductor muscles fired during inspiration, while the adductors showed an activity during expiration, and that the inflation of the lungs abolished the activity in the abductor and excited the discharge in the adductors

As these muscles were relatively inaccessible to the electromyographic examination in a human subject, it was decided to explore the movements which take place in anesthetized experimental animals

METHOD

Dogs were used throughout the experiments, anesthetized with intravenous sodium pentobarbitone, about 30 mg/kg body weight The neck was opened at the mid-line, and the larynx was exposed, carefully avoiding injury to nerves and blood vessels Access to the muscles was obtained by direct visual controls Sometimes the trachea was cut at the lower margin of the larynx, in such cases the animals no longer breathed through the larynx In order to produce dyspnea, animals were connected to a rebreathing bag, allowing them to rebreathe a limited volume of oxygen and to accumulate carbon dioxide

Electromyographic recording was made by inserting a concentric needle electrode The needle electrode led to a cathode ray oscillograph and loud speaker via a resistance capacity coupled amplifier The action potentials were recorded by using a magnetic type oscillograph on a sheet of moving bromide paper on which the pneumograph was recorded simultaneously

As the needle electrode of this type is not sufficiently selective to give information on the pattern of a single motor discharge, special care was taken to avoid an intermingling of the activities of other adjacent units, because, if more than three or four units were active it would be difficult to interpret the electrical records

RESULTS

The electrical activity in five intrinsic laryngeal muscles was examined The thyro-arytenoid, crico-arytenoid lateralis and interarytenoid are the adductor muscles which cause approximation of the vocal cords with consequent narrowing of the glottis The crico-thyroid is believed to regulate the length or tension in the cords, and to complete the degree of adduction On the other hand, the crico-arytenoid posterior abducts the arytenoid cartilage and widens the glottis

When the needle electrode was inserted into the muscle, it was found that the adductors, except the thyro-arytenoid, which remained quiet throughout the whole respiratory cycle, showed activity during expiration, while the abductor was active during inspiration The features of motor neuron discharge which were recorded from the intrinsic laryngeal muscles during respiration, were similar to those described by Adrin and Bronk,[2] Bronk and Ferguson,[3] and Gesell, Magee and Bricker[6-] for the phrenic and intercostal neurons, that is, during quiet breathing only a fraction of the motor units was active, and the activity in most of these consisted of a short train of impulses The records exhibiting a characteristic pattern are illustrated herewith (see Fig 1) Discharge frequencies of a single unit operating phasically were between five and 50 impulses/sec In the adductors the frequency of impulses was the greatest at the start of expiration and gradually dropped away as expiration proceeded, and ceased at the end of expiration On the other hand, in the abductor muscles the frequency was low at the start of inspiration and rose gradually as inspiration proceeded, *i e*, the intervals between successive impulses became progressively shorter Its increasing rate of discharge reached a peak at the end of inspiration, where the firing abruptly ceased at or before expiration

Although the majority of the motor units fired phasically, some units (see Fig 2) showed a continuous train of impulses whose frequency rose and fell with the respiratory cycle, as if the steady continuous frequency was modulated by the rhythm of breathing These units fired continuously expiration Recently an investigation on impulse activity of the recurrent nerve and electromyographic recording of activity in the intrinsic laryngeal muscles was reported by Green and Neil,[8] showing that the abductor muscles fired during inspiration, while the adductors showed an activity during expiration, and that the inflation of the lungs abolished the activity in the abductor and excited the discharge in the adductors

As these muscles were relatively inaccessible to the electromyographic examination in a human subject, it was decided to explore the movements which take place in anesthetized experimental animals

METHOD

Dogs were used throughout the experiments, anesthetized with intravenous sodium pentobarbitone, about 30 mg/kg body weight The neck was opened at the mid-line, and the larynx was exposed, carefully avoiding injury to nerves and blood vessels Access to the muscles was obtained by direct visual controls Sometimes the trachea was cut at the lower margin of the larynx, in such cases the animals no longer breathed through the larynx In order to produce dyspnea, animals were connected to a rebreathing bag, allowing them to rebreathe a limited volume of oxygen and to accumulate carbon dioxide

Electromyographic recording was made by inserting a concentric needle electrode The needle electrode led to a cathode ray oscillograph and loud speaker via a resistance capacity coupled amplifier The action potentials were recorded by using a magnetic type oscillograph on a sheet of moving bromide paper on which the pneumograph was recorded simultaneously

As the needle electrode of this type is not sufficiently selective to give information on the pattern of a single motor discharge, special care was taken to avoid an intermingling of the activities of other adjacent units, because, if more than three or four units were active it would be difficult to interpret the electrical records

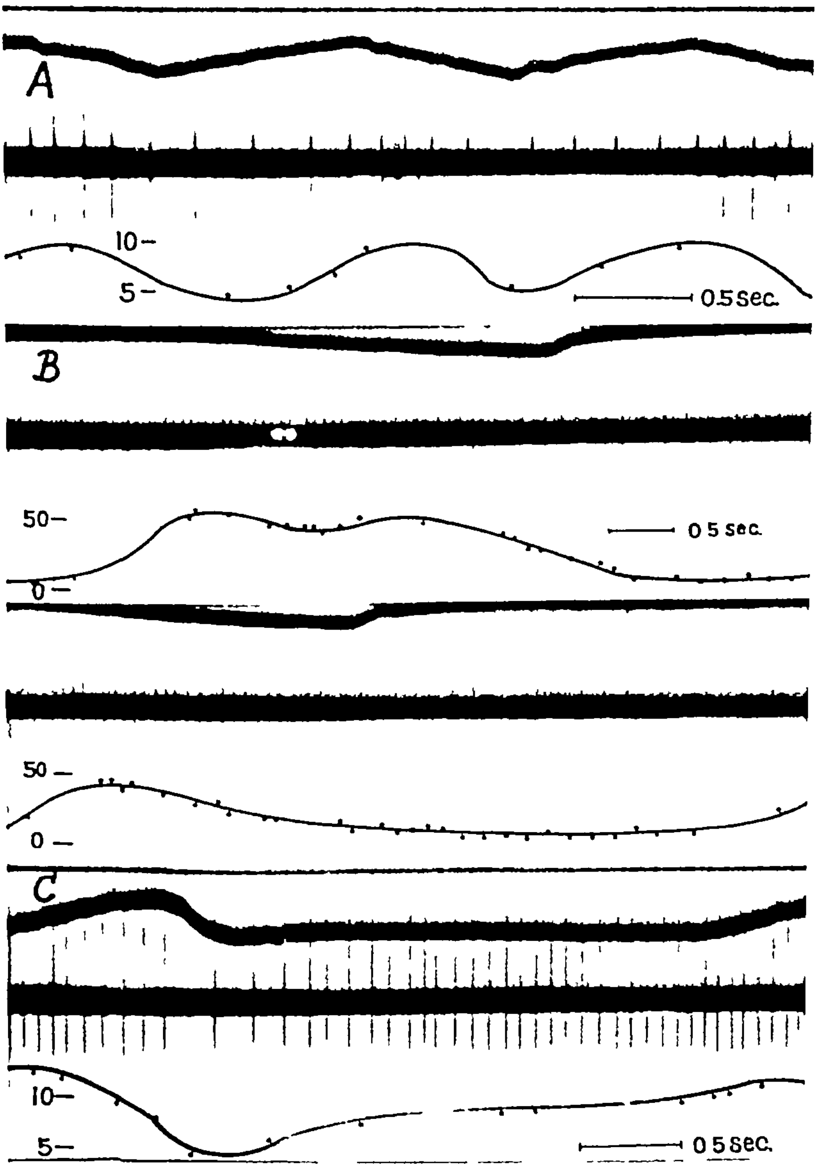


Fig 2 Continuously discharging unit recorded from the adductors (A) (B) and abductor (C) These units fired continuously throughout inspiration and expiration but in adductors increasing in rate during expiration and in abductor increasing in rate during inspiration Upper line is pneumogram upwards movement indicating inspiration Lower line is graph of impulse frequency

throughout inspiration and expiration the abductor increasing in frequency during inspiration, while the adductors increased in rate during expiration Many of the continuously discharging units fired at rather slow rate, namely, they increased their frequency from the range of 5-10 impulses/sec during rest, to the range of 10-20 impulses/sec during contraction, however, sometimes a considerably high rate was observed, 50-60 impulses/sec (see Fig 2-B)

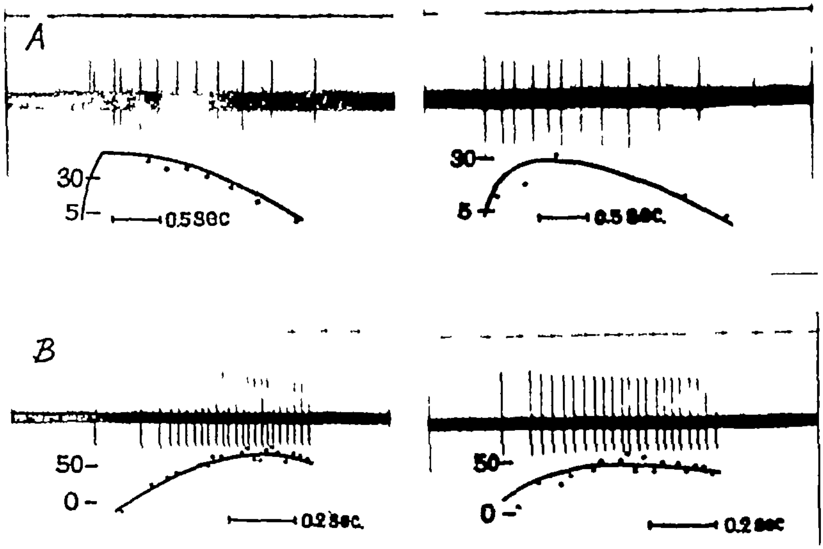


Fig 1 Electromyogram recorded from crico-arytenoideus lateralis (A) and crico-arytenoideus posterior (B) The adductor shows decelerating activity, while the abductor exhibits a characteristic accelerating pattern Lower line is graph of impulse frequency

It may be assumed that functionally the motor units in laryngeal muscles fall into two groups The members of the first group perform a phasic contraction during respiration and those of the second group serve to maintain the muscle tone underlying the phasic movements

When respiration was stimulated by causing animals to rebreathe a limited volume of air the frequency of discharge

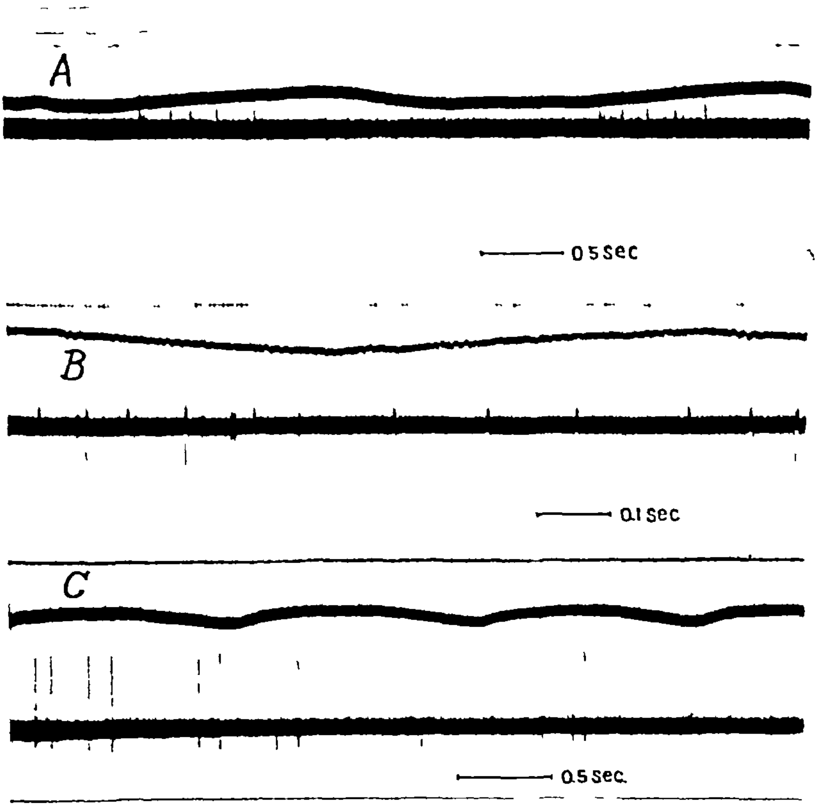


Fig 4 Electromyogram recorded from crico-thyroideus (A) continuously discharging unit of crico-thyroideus (B) and of crico-arytenoideus posterior (C) showing the effects of anesthesia on respiratory activity The impulse frequency decreased and intervals of each successive impulse become more or less at random Upper line pneumogram (expiration down)

fibers discharging impulses decreased so that the number firing in a train became fewer The pattern of discharge lost its characteristic nature, and intervals of each impulse became more or less at random

In order to eliminate the influence of air current on the muscle movements, the trachea was sectioned at the lower end of the larynx No appreciable change in activity was observed, even when air was artificially blown into or sucked through the larynx asynchronously with the respiratory rhythm When dyspnea was produced, an increase in activity

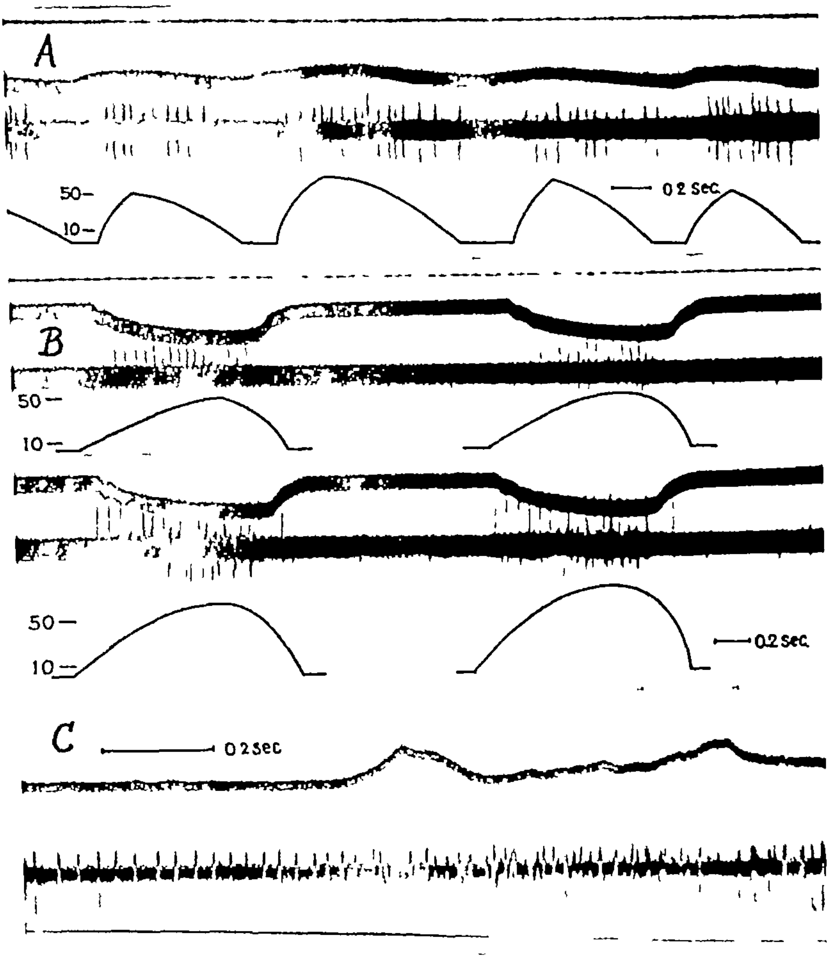
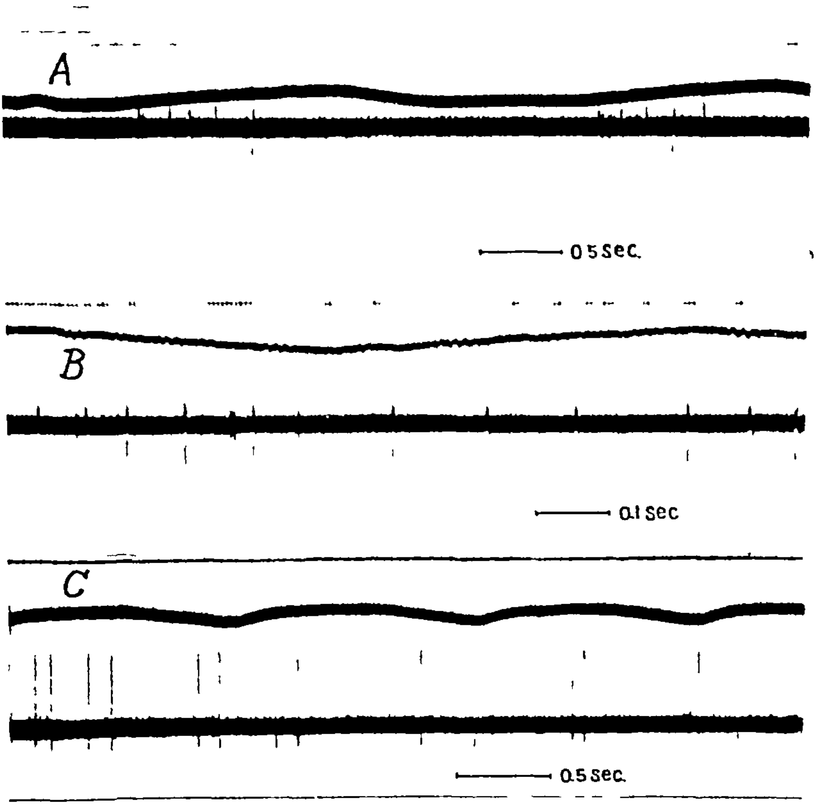


Fig 3 Electromyogram recorded from crico-arytenoideus lateralis (A) crico-arytenoideus posterior (B) and continuously firing unit in crico-thyroideus (C) during dyspnea The frequency of firing increased and other unit discharging impulses were recruited Upper line is pneumogram (expiration down) and lower line is graph of impulse frequency

and the train of impulses increased, and additional motor units which discharge impulses, were added or recruited (see Fig 3) Continuously firing units also increased in their frequency as respiratory movements became more violent

Effects of anesthesia are illustrated in Fig 4 In such a case the frequency of impulses and the number of active



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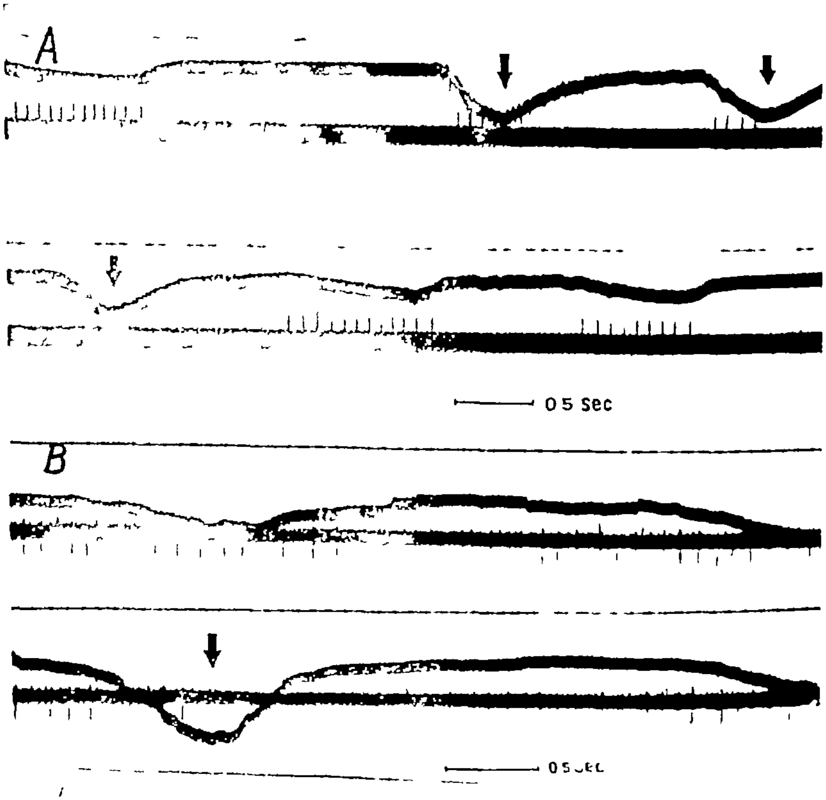


Fig 5 Effect of inflation of lungs upon a phasically operating unit (A) and a continuously discharging unit (B) Arrows indicate inflation Diminishing and abolishing of activity after inflation is obvious Upper line is pneumogram

invariably took place, regardless of an air flow through the larynx It seemed that the laryngeal respiratory movements were not affected by local sensory information evoked by the force of air current

The abolition of phasic activity in adductor muscles caused by inflation of lungs, reported by Green and Neil,[8] was also confirmed (see Fig 5-A) Fig 5-B shows the effect of inflation upon continuously discharging units After strong inflation a continuous train of impulses during inspiration became abolished, but, during expiration they fired as usual

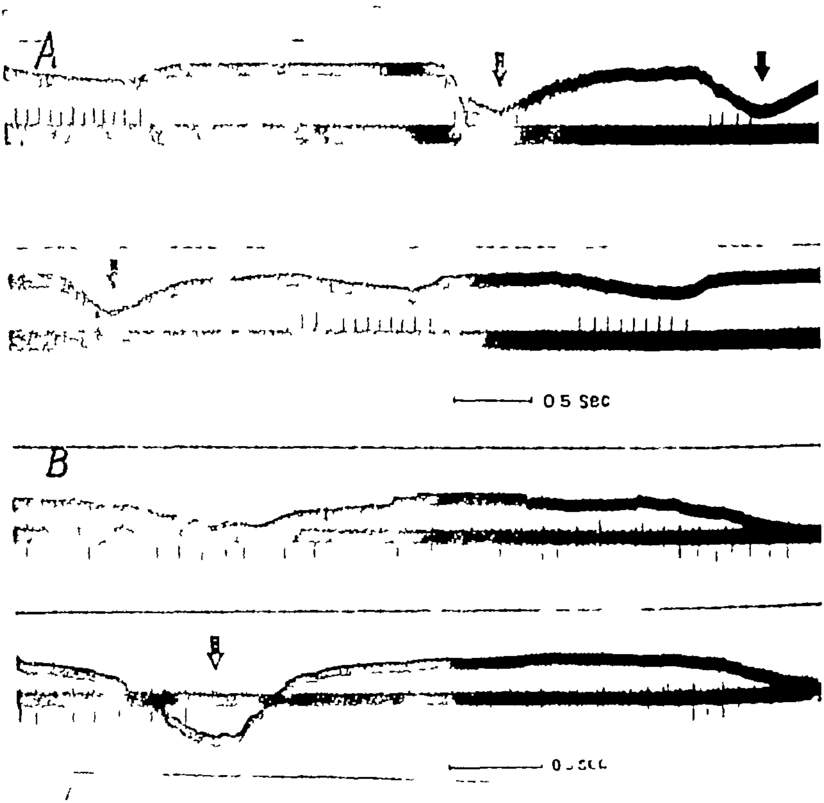
DISCUSSION

The firing pattern in the adductor muscles of the larynx would be regarded, according to Gesell and others, as a rapidly augmenting type characteristic of the intrinsic expiratory muscles, and that of the abductors as a slowly augmenting type characteristic of the genuine inspiratory muscles In respiratory activity the laryngeal muscles' response is similar to that of the intrinsic respiratory muscles in anesthesia, dyspnea, and the reflex evoked by stretch receptors in the lungs It might, therefore, be concluded that during respiration the motor neurones innervating the laryngeal muscles are influenced by the respiratory centers in a manner similar to those of the genuine respiratory muscles

The intrinsic laryngeal muscles exhibit a basic tonic activity, as suggested by Jackson and Jackson[12] The periodic widening and narrowing of the glottis is superimposed upon this underlying muscle tone The tonic activity in respiratory muscles is said to have a significant role in maintenance of posture, particularly against the force of gravity, but, as in the larynx, the force of gravity acting on the cords might be so slight and negligible that it would not be unreasonable to suppose that movements of the cords would take place around the mid-position which might be determined by the balance between these tetanic contractions in a larger or smaller portion of motor units in the antagonistic muscles

The problem, as discussed by Andrews[13] on the respiratory displacement of the larynx, "How is the balance maintained?" has not yet been explained satisfactorily The continued activity of the laryngeal muscles during respiration after the detachment of the trachea and the great increase in activity when dyspnea was produced, indicate that the position or movements of the cords are not passively determined by the force of air current through the glottis chink

It is said that the laryngeal muscles, as well as the muscles of the tongue, face and middle ear do not contain muscle spindles[11] Fernand and Young[5] have classed the recurrent laryngeal nerve in rabbits as unimodal, containing few or no proprioceptive fibers Campbell and Murtagh,[4] reporting the



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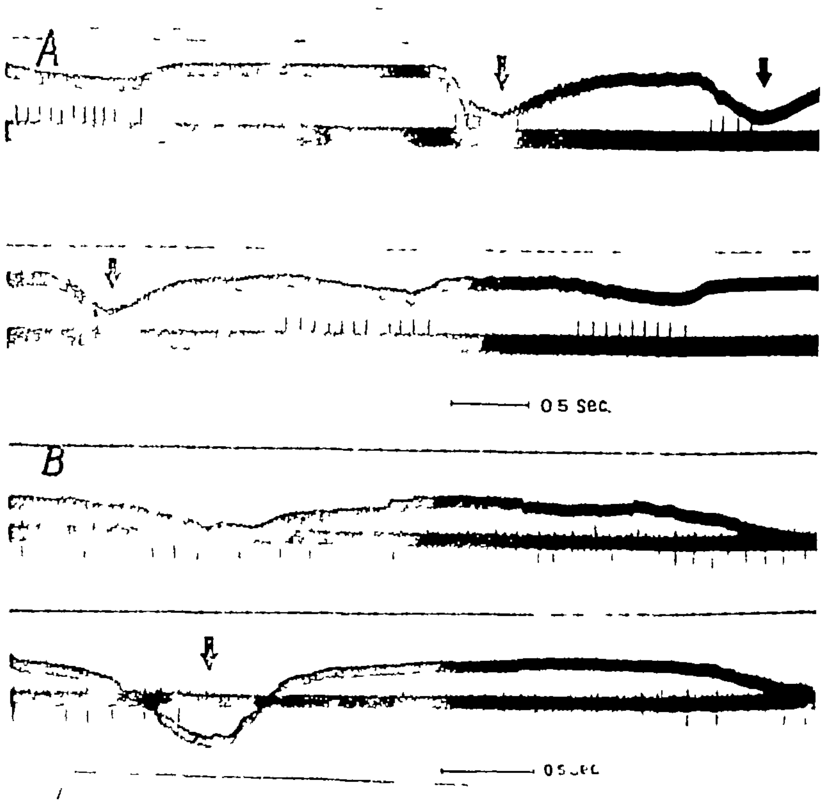

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Regarding the useful results of respiratory movements of the glottis, there is no doubt that the effect of widening at the glottis chink at or just *before* inspiration is a reduction of resistance to an inflow of air. On the other hand, the effect of the constriction, beginning prior to expiration and continuing through it, is suggested by Pressman[10] to have a significance upon the phenomenon of air mixing within the lungs. It is widely known that respiration is shallow and somewhat irregular in case of a laryngectomized patient. This might probably be due to the lack of resistance or, in other words, appropriate "load" to an outflow of air. It might be safe to say that the laryngeal muscles, as well as the muscles of the wings of the nares and bronchi, should be called "the regulatory muscles of the respiratory passage," which serve to regulate the section of the respiratory passage, reducing the resistance to inspired air, and giving it the appropriate load to keep respiration deep and regular.

SUMMARY

The electrical activity in five intrinsic laryngeal muscles of the dog during respiration was examined with electromyographic recordings. The abductor was active during inspiration, while the adductors showed activity during expiration, except the thyroarytenoideus, which remained quiet throughout the respiratory cycle.

The pattern of activity in the laryngeal muscles showed a close similarity to that of intrinsic respiratory muscles.

No change in activity after the detachment of the trachea indicates that respiratory movements of the glottis may be controlled centrally without reference to a local sensory information Effects of respiratory movements upon respiration were discussed

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NYSTAGMOGRAPH FOR CLINICAL USE[*]

VICTOR GUILLEMIN, JR , Ph D ,[†]
and
NICHOLAS TOROK, M D ,[‡]
Chicago, Ill

The photoelectric nystagmograph presented in this paper is similar in its principle of operation to the instrument described previously by Torok, Guillemin, and Barnothy[1] The equipment described here is, however, much lighter and more compact, and incorporates several improvements that result in greater reliability and in simpler, quicker and more convenient recording of nystagmic eye motions

The entire optical and photoelectric system of the new instrument is mounted upon a headband and goggle frame fitted to the patient Recordings may be made with the patient in any position, seated, in bed or on a revolving chair Preparation of the patient for a recording may be accomplished in a minute or two so that the whole process of making a record, either by thermic stimulation or by means of the rotating chair, requires little more time than the usual clinical procedure of visual observation of nystagmus

The advantages of graphical recording are obvious A graphical record shows many details that are not obtainable by direct observation, and an analysis of the graph provides data on the duration, frequency, change of frequency, amplitude and form of the nystagmus, that are valuable both in clinical practice and in vestibular research[2,3]

Most of the recordings of nystagmus make use of the corneo-retinal potential difference picked up by electrodes placed at various positions in the immediate vicinity of the

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[†] Department of Physiology University of Illinois College of Medicine

[‡] Department of Otolaryngology University of Illinois College of Medicine

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eye The usefulness of this method is clearly demonstrated in the recent work of Aschan et al[4], who obtained very reliable and instructive nystagmographs in serial clinical investigations We cannot agree, however, with the statement of these authors that the photoelectric method has been superseded by the method of potential pick-up On the contrary, our experience in the laboratory and in the clinic shows that our photoelectric method gives excellent records and is most practicable in terms of convenience and economy of time required to obtain a record

As previously described, the instrument makes use of the difference in reflection of infrared light from the dark iris and the light sclera of the eye A focused beam of infrared light forms an illuminated area on the eyeball approximately 1 mm wide by 16 mm long, so situated that it lies partly on the iris and partly on the sclera as shown in Fig 1-A This position is appropriate for the observation of horizontal nystagmus To record vertical motions, the light beam is oriented as shown in Fig 1-B The light beam is fixed relative to the patient's head, therefore, any motion of the eyeball will vary the portion of the beam striking the sclera Since the sclera has a higher reflectivity for infrared, as compared to the iris, the total amount of light reflected from the eyeball will change with every movement of the eye This reflected light falls upon a photocell, located close to the eyeball, and

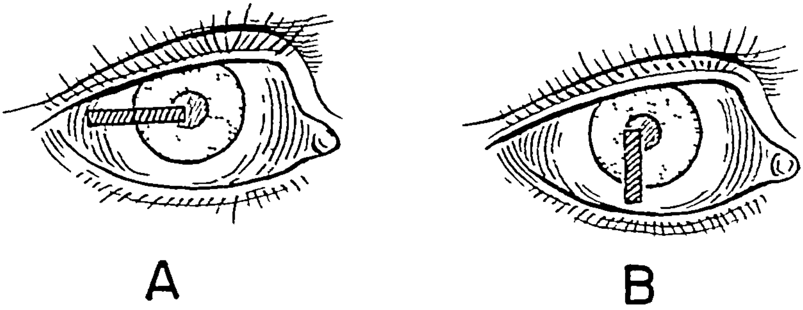

Fig 1

is converted to corresponding changes of electrical potential that are electronically amplified and recorded

Fig 2 shows a schematic diagram of the complete optical and electronic equipment arranged for recording nystagmus on the revolving chair The same equipment is used when thermic stimulation is employed, except that the connections through rotating slip rings and stationary bruches are unnecessary

Immediately in front of the eye, which is illuminated as described, are a pair of photocells These are Bell laboratory photovoltaic cells (sun batteries) in the form of small flat rectangular plates, 5 mm by 20 mm They are connected electrically in series so that their output is additive, that is, they function as a single cell

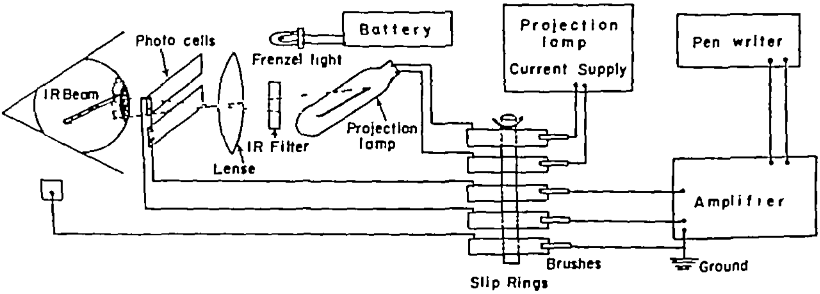

Fig 2

The light source is a special projection lamp having a single straight filament that acts directly as a source of illumination A short focus projection lense focuses an image of this filament upon the eyeball A glass infrared filter is interposed in the light beam to absorb the visible light of the lamp This prevents visual stimulation of the eye during the recording of nystagmus The filter is mounted in a sliding holder so that it may be moved out of the path of the beam for visual focusing and positioning of the image on the eyeball

A 20-diopter lense is mounted directly before the opposite eye to be used for visual observation when desired, in the manner of the Frenzel glass A small electric lamp, located behind this lense, gets its current supply from a portable dry cell battery This lamp is well shielded and operates at low intensity, just sufficient to permit visual observation of the eye in a darkened room

All the parts described thus far, with the exception of the dry cell battery, are mounted on a headband and goggle frame fitted to the patient's head

Electrical connections from the photocells on the revolving chair to the stationary electronic amplifier are made via the usual slip rings, revolving with the chair, and stationary brushes bearing on these rings Two similar connections are used for the electric current supply of the projection lamp This is provided by a well-filtered low-voltage direct current source that is operated on the 115 volt, 60 cycle power lines It is essential to operate the projection lamp on steady direct current, since the photoelectric system is fast enough to respond to the 120 cycle per second light intensity fluctuations of a lamp operating on alternating current This direct current source is controlled by a switch having a "low" intensity position, used while focusing the beam on the eye, and a "high" position used when the infrared filter is moved into the light beam

The amplifier is of the a c type with a flat frequency response over the range of one-half to 200 cycles per second This range is adequate for recording practically all types of nystagmus, both spontaneous and induced, without appreciable distortion The amplifier is provided with an electronic limiter that prevents excessive output signals due to blinking or large voluntary eye movements The amplifier actuates a commercial pen recorder having a frequency response range of zero to approximately 100 cycles per second The recorder thus limits the overall upper frequency response of the equipment

The actual construction of the headband, goggle frame and optical equipment, is shown in Fig 3, which shows both a front and back view The housing for the projection lamp,

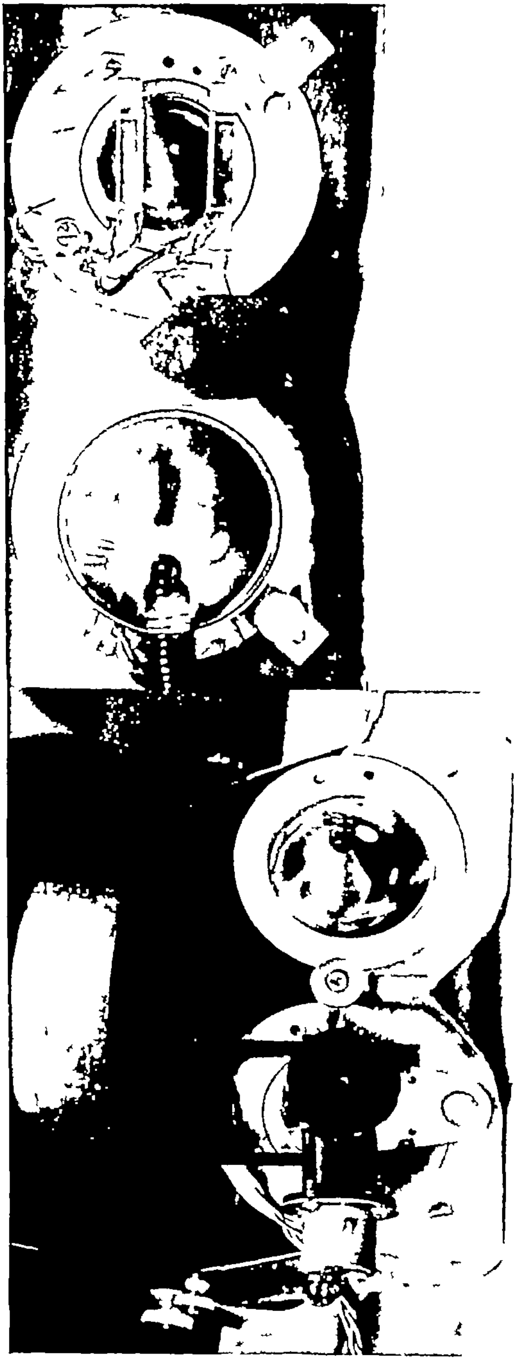

Fig 3

lense and infrared filter in its retractable slide is shown to the left of the front view This whole assembly is mounted as a unit, in a sliding and rotating ball-and-socket joint that permits axial motion for focusing and also angular rotation In addition, the optical assembly may be tilted in all directions for adjusting the beam to its proper position on the eyeball All these adjustments are fixed by tightening a single thumb nut Further adjustments are provided for headband size and nose configuration

The Frenzel glass, together with its small illuminating lamp, is mounted on the opposite side of the goggle frame, and both the Frenzel glass and the optical assembly are mounted upon circular metal discs that fit into semicircular openings in the goggle frame They are held in place by thumb screws and are easily removable from the goggle frame so that their positions may be interchanged, that is, the light beam may be positioned on the right eye with the Frenzel glass before the left eye, or vice versa

The rear view of the goggle frame shows the projection lense with the two photocells before it, and the small lamp of the Frenzel glass Fig 4 shows the apparatus fitted to the patient's head

The two photocells, as stated above, act as one Actually, one cell would suffice, however, because of the great variation of head and nose sizes and shapes, the light beam may fall upon the eyeball in a slightly upward or downward slanting direction with various patients so that the reflected beam is directed respectively, somewhat downward or upward In either case, one or the other of the two cells will be well illuminated by the reflected light Thus, with two cells, the adjustment of the beam is less critical, and may be accomplished quicker and more easily

The rotating chair (see Fig 5), used with the above equipment, was assembled at low cost and is adequate for routine clinical tests It has an electrical variable speed drive giving a range of angular velocities of the chair from 2 5 to 90 degrees per second (0 42 to 15 turns per minute) in either direction of rotation There is no adjustment for angular acceleration or deceleration The chair reaches full angular velocity, upon starting, in about two seconds, and is stopped by a hand brake in less than one second

Calibration of the equipment, in millimeters of pen excursion per degree of eye deflection, is accomplished by means of a simple perimeter (see Fig 5), having two small neon lamps that may be positioned at various angular separations as measured at the patient's eye, from 5 to 30 degrees of arc A hand switch shifts the illumination quickly from one lamp to the other, and the patient is instructed to follow the light with his eyes while keeping his head at rest

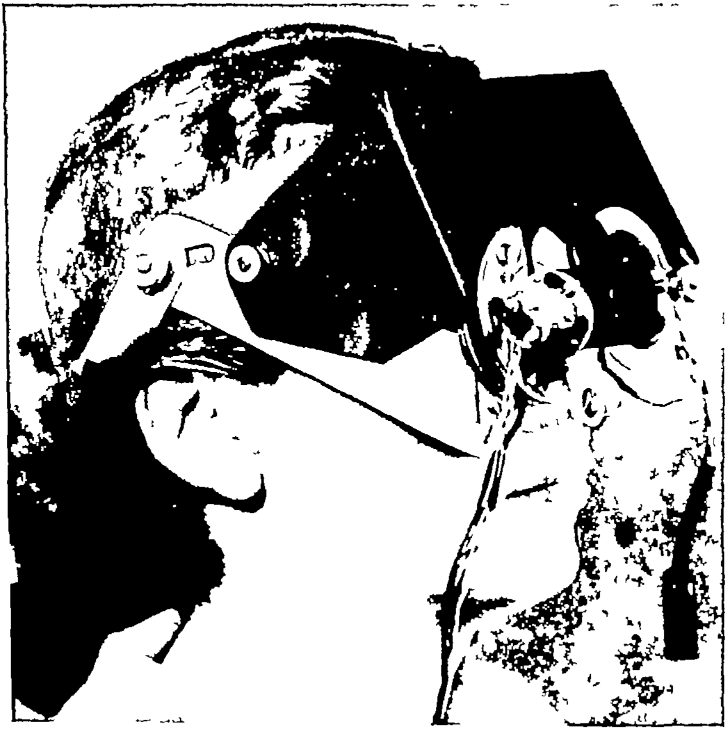

Fig 4

The whole equipment is inherently linear in response to well within its limit of precision, which is about 0 2 mm for visual measurement of the pen record This degree of linearity is found in the output of the photocell, in the response of the amplifier, and in the excursion of the pen recorder, however, when carrying out a calibration on a given patient there is a large factor of uncertainty, depending upon the precision with which he can follow the apparent motion of the light on the perimeter A trained and cooperative subject can repeat successive eye movement for the same perimeter setting within about 2 per cent, but an untrained or uncooperative patient may vary his eye motion as much as 10 or 20 per cent at the same setting In such cases only a very rough calibration can be accomplished

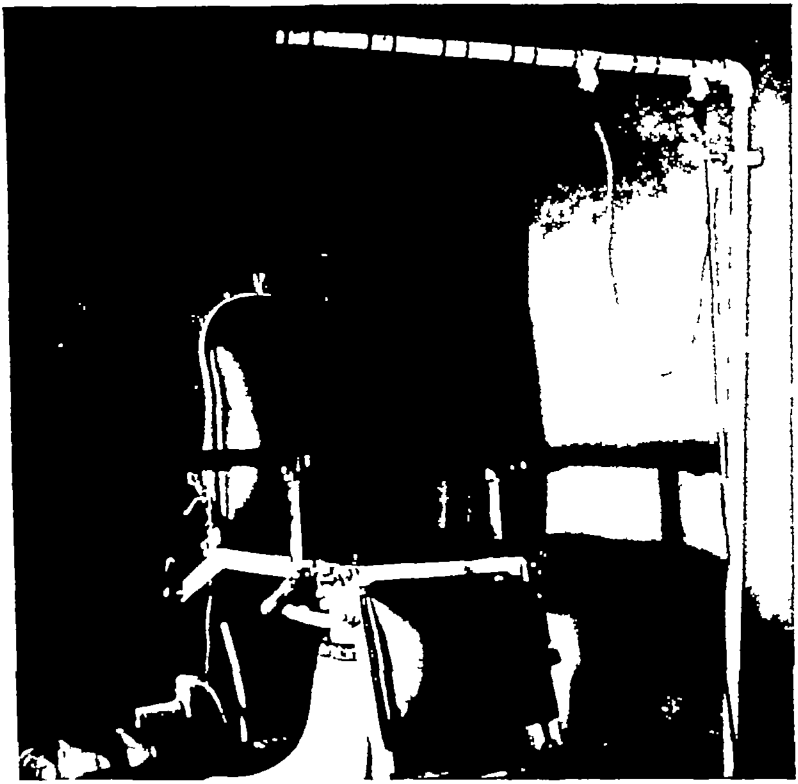

Fig 5

The overall sensitivity is ample for all recordings A motion amplification of twenty to one is obtained readily, that is, a linear motion of 0 5 mm at the surface of the eye may produce a pen excursion of 10 mm Thus it is possible to record nystagmic motions so minute that they would not be noted by visual observation of the eye

Photoelectric recordings of nystagmus has been described and used successfully by Pfaltz and Richter[5] The principle of operation of their apparatus is, however, somewhat different They illuminate the entire area of the iris plus the near adjacent areas of the sclera on both sides of the iris Two photocells, positioned laterally and connected in opposition, so that their output potentials are opposed, record the simultaneous and opposite changes of illumination on both sides of the iris when the eye moves

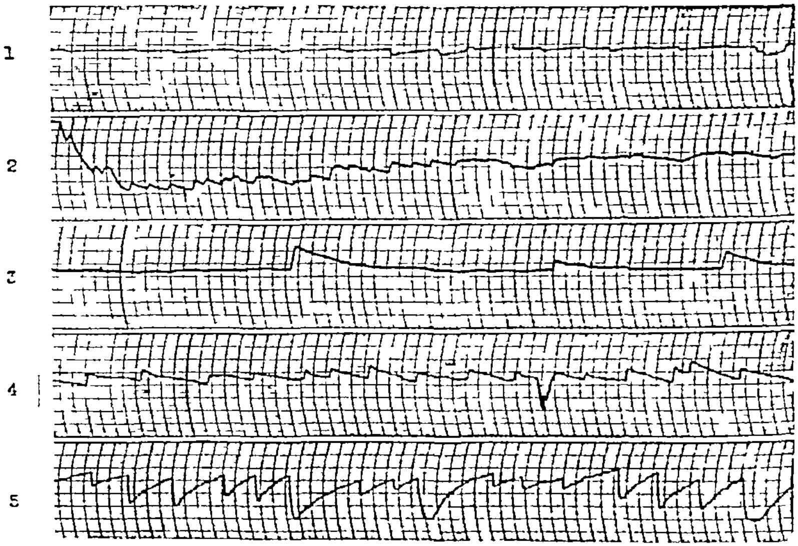

Fig 6 Nystagmograms of Various Types Five horizontal bars represent 1 sec time 1 Spontaneous nystagmus small amplitude constant frequency 2 Postrotatory nystagmus obtained through the electrically driven chair 45 /sec velocity and sudden stop total duration within normal limits nystagmus frequency elevated 3 Postrotatory nystagmus obtained under identical conditions as graph No 2 total duration normal very low frequency but larger amplitude 4 Thermic nystagmus obtained by 10 cc 68 of water even amplitude normal frequency the one irregular excursion downward is the result of a blinking of the eyelids 5 Thermic nystagmus 10 cc 68° water larger and uneven amplitudes frequency within average normal limit

With the use of a focused light beam as described here, only one iris-sclera boundary is illuminated It is thus possible to make recordings of first degree nystagmus where the eye is deflected so far to the side that one edge of the iris is occluded by the eyelids When both second and first degree nystagmus is to be recorded in succession, the beam may be so positioned that one or the other edge of the iris lies well within the beam both in the forward and the sideways deflected position of the eye

The photoelectric study of nystagmus requires that the eye be held open during the actual time of recording This does not appear to have any effect upon the nystagmic response when the patient is in a darkened or dimly lighted room The opened eye is, of course, required in any case where the recording is to be checked by simultaneous observation through the Frenzel glass Actually this means of observation was provided in the present apparatus primarily to check its operation during the development and testing period The recorder has proven so reliable that visual observation is seldom used in routine clinical tests

Fig 6 shows several typical records obtained with the photoelectric nystagmograph

SUMMARY

This paper describes a photoelectric nystagmograph, using invisible infrared light, suitable for recording all types of nystagmic eye motions, except pure rotatory nystagmus It is particularly well adapted for routine clinical tests with thermic or rotatory stimulation, but is also suitable for physiological research It provides very reliable records that show all the details of form, amplitude, frequency and duration of the vestibular reaction

The apparatus comprises a headband and goggle frame, fitted to the patient's head, upon which the optical and photoelectric equipment is mounted This is connected to an electronic amplifier and pen recorder that supplies an immediate pen record of the nystagmus

The recording is conducted in a dimly lighted room The

motions of one eye supply the infrared light signals for the recorder The other may be observed simultaneously, if desired, through a 20-diopter lense in the Frenzel method

By a simple operation the optical assembly and the Frenzel glass may be interchanged so that either eye may be used to supply the record

In clinical use, recordings may be made in only a few more minutes of time, and with no more discomfort to the patient than in the usual procedure of visual observation of nystagmus

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SHAMBAUGH PRIZE—COLLEGIUM ORLAS

Dr Glen E Wever, of Princeton, was recently awarded the Shambaugh prize which is presented every second year by the Collegium Otorhinolaryngologicum Amicitae Sacrum, for outstanding work on the physiology of the auditory organ

EUSTACHIAN TUBE BIOPSY CANNULA

MAHMOUD K MUFTIC, M D ,*

Basrah, Iraq

Tubal obstruction usually affects the nasopharynx in various ways ranging from acute and chronic inflammation of the adenoids to benign neoplasm and hypertrophy of the nasopharyngeal tissues

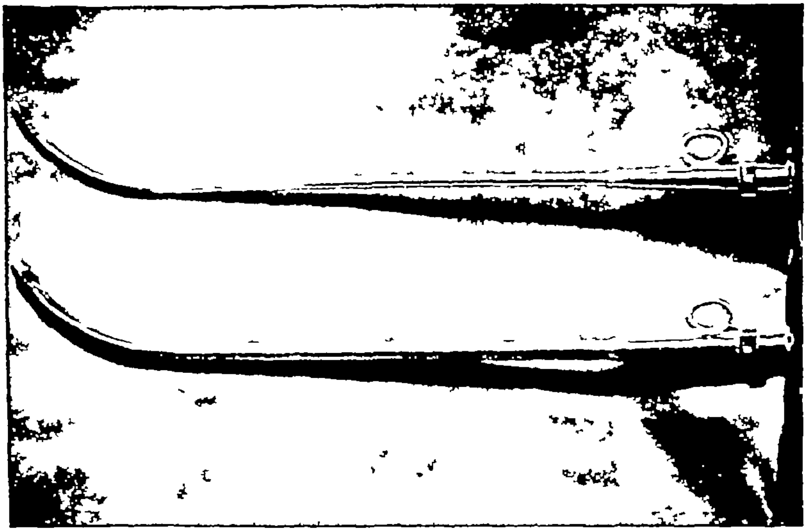

Fig 1 Muftic s Biopsy Cannula for Eustachian Tube

The usual procedures for investigating the cause of tubal closure, posterior rhinoscopy, nasopharyngoscopy, tubal insufflation, etc , were not productive of proper analysis in the case in question, consequently it was necessary to establish a simple routine procedure which would permit biopsy from the tubal orifice and from Rosenmuller's fossae, thus giving a histopathological diagnosis of the obstruction

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*King Fassail Royal Hospital Basrah

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To simplify the technique, an instrument† for obtaining specimens for biopsy was designed in the shape of a Eustachian tube catheter adaptable to a B-D syringe (LL) The end piece may be of two different types resembling the endometrial cannula-curette according to Raydal and Novak, but of a smaller size

This cannula-curette is introduced by the same technique as in ordinary catheterization of the Eustachian tube The catheter is introduced (with or without local anesthesia), and when it is engaged in the tubal orifice or well in Rosenmuller's fossa, strong suction is applied by aspirating the syringe or adapting cannula to a suction unit After complete suction, the cannula is withdrawn and the tissue is removed from the cannula by strong insufflation, and placed in the proper fixing solution

The stain for the small biopsy is made according to Papanicolaou, and thicker pieces are embedded for histopathological investigation by the usual staining techniques

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†These instruments are made from my design by Down Bros and Mayer and Phelps 92 Borough High Street London S E 1 to whom I am most grateful

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AMERICAN SOCIETY OF FACIAL PLASTIC SURGERY

The Annual Spring Meeting of the American Society of Facial Plastic Surgery will be held March 10-11, 1958, at Columbus, Ohio For further details write Dr Samuel M Bloom, Secretary, 123 East 83rd Street, New York (28), N Y

ANESTHESIA METHODS FOR BRONCHOSCOPY AND THEIR USEFULNESS IN PRACTICE*

E J KNUDSEN, M D ,
H RASMUSSEN, M D ,
H RUBEN, M D ,
and
P TRAUN-PEDERSEN, M D ,
Copenhagen, Denmark

Bronchoscopy, when introduced into clinical practice about the turn of the Century, was employed chiefly for removal of foreign bodies In the course of years, the use of diagnostic bronchoscopy has steadily increased

Bronchoscopy, carried out in deficient anesthesia, is an extremely disagreeable experience to the patient, moreover, the diagnostic value of bronchoscopy in a patient offering resistance is doubtful, and finally, bronchoscopy under such circumstances involves a risk of injury

Endeavors have, therefore, been made to find a satisfactory method of anesthesia, but the multiplicity of proposals proves the difficulty of the task The main troubles are that the anesthetist and the surgeon work in the same field and, therefore, easily get in each other's way, and that the field concerned is sensitive with very brisk reflexes

Formerly, the choice lay between local and general anesthesia, the latter in the form of inhalation anesthesia Within recent years a number of methods, new in principle, have been introduced We have found it appropriate to try some of these in practice and attempt to assess their usefulness

The demands to be made on an ideal method are the following

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*From the Finsen Institute Copenhagen Anesthesiology Department (Head H. Ruben M.D) and E N T Department (Head H Rasmussen M.D)

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1 A minimum of risk to the patient

2 Removal of discomfort to the patient

3 Undisturbed working conditions for the surgeon

4 Simplicity of technique and apparatus

5 A short restoration period (of particular importance in cases of out-patients)

Local anesthesia, with or without premedication, was previously the most frequently employed method for adults, and is still used in some cases With reference to the above-mentioned demands, it is seen that

1 The method, on the assumption of adequate dosage, fulfills the requirement of safety

2 In few cases only does it remove the discomfort to the patient

3 It rarely renders possible undisturbed examination In cases of nervous patients it is impossible to carry through bronchoscopy in local anesthesia alone

4 The technique is simple

5 It is suitable for out-patients

In cases unfit for local anesthesia inhalation anesthesia was previously the only other possibility Examination then had to be performed during the restoration period, after the dosage had been stopped The examination requires deep anesthesia The degree of the consequent depressed respiration and a possible cyanosis are difficult to follow during endoscopy in a dark room The anesthetist will often have to intervene while the surgeon is at work, either to ventilate with oxygen or to add a supplementary amount of ether, for instance In case of difficulty with the introduction of the bronchoscope, a laryngeal spasm may occur, which will often start a series of unpleasant complications Regarding the above-mentioned demands we have found that

1 The method is not without risk

2 The discomfort of bronchoscopy is replaced by discomfort of anesthesia

3 The surgeon cannot work undisturbed

4 The technique certainly is simple, but it is difficult to manage in practice

5 The restoration period is fairly long, and the method, therefore, is unfit for out-patients

The only cases where inhalation anesthesia may be indicated are those of bronchoscopy in children, where the modern forms of general anesthesia may be difficult to administer In cases of children with obstructing or potentially obstructing foreign bodies in the air passages any kind of general anesthesia must be regarded as contra-indicated Non-obstructive foreign bodies in the air passages of children can often be removed in vinyl ether-and-ether anesthesia, but an excellent method has been indicated by Toker, using thiopental-sodium and succinyl-choline-iodide, and cuirass respirator *(vide infra)*

MODERN ANESTHETIC METHODS

A Local anesthesia suplemented by general analgesia, obtained with pethidine intravenously

B General anesthesia obtained with barbiturates supplemented by short-acting relaxants

A Local Anesthesia Supplemented by Pethidine Medication

A previous investigation showed that endoscopy through the pharynx, including bronchoscopy, could be greatly facilitated by injecting pethidine intravenously, due partly to the depressing effect of pethidine on the laryngeal and pharyngeal reflexes, and partly to the mentally relaxing and pain-stilling action of pethidine in the doses used, an action which may be characterized as one of general analgesia Not infrequently there is found amnesia with regard to discomfort of the examination

The method has now been employed for bronchoscopy in more than 400 cases at the Finsen Institute during the past six years, with an exceedingly favorable result With reference to the previously mentioned demands we have found that

1 The risk involved must be supposedly less than that of local anesthesia alone, as the amount of anesthetic, if pethidine is used, can be reduced Oximetry shows that the reduction of the oxygen saturation in cases with pethidine medication is slight, being of the same order as at bronchoscopy in local anesthesia alone, where a reduction occurs when the bronchoscope causes obstruction, *e g*, when it is introduced into one of the bronchi This can possibly be explained by the way in which the depressing effect of pethidine on the respiration is abolished by the stimulating effect of the intervention itself

2 Pethidine greatly reduces the discomfort to the patient Reactions in the form of nausea are rare, the skin occasionally becomes pale and slightly moist, but the blood pressure does not fall, and there is seen only the minor rise in pulse rate which corresponds to the parasympathicolytic action of pethidine Liberation of histamine with transitory redness along the course of the vein has been seen in a few instances, but no bronchospasms or collapse

3 By employing local anesthesia it has, in the great majority of cases, been possible to carry through undisturbed and thorough bronchoscopy, most often including the taking of biopsy specimens and use of the telescope

4 The method is simple and, if necessary, can be practiced by the surgeon alone, aided only by a nurse to watch the patient during and after the operation

5 The method is suitable for out-patients, the majority of whom can resume their daily work after a few hours' rest After removal of the bronchoscope the cough reflexes will suffice to bring up any blood or mucus

Technique

We used between 50 and 200 mg (on an average about 100 mg) pethidine in a 1 per cent solution A good technique of local anesthesia is required to obtain a favorable result

After careful spraying of the mouth and throat, 8 to 10 ml of one-half per cent pontocaine with adrenaline 1 200,000 can, with advantage, be injected in between the vocal cords by means of a syringe fitted with a blunt, curved cannula, which can be passed down behind the epiglottis of the sitting patient The cough produced by the application will spread the injected pontocaine in the trachea and bronchi

Intravenous injection of pethidine is thereafter started, up to 50 mg is given within about 30 seconds, and afterwards supplemented according to requirement Maximum response to intravenously injected pethidine is obtained after a few minutes

B General Anesthesia

The use of barbiturates combined with relaxants was first described about four years ago, and various modifications of the technique have already been suggested These represent different solutions of the essential problem of oxygenation during the induced apnea

Evaluation of the barbiturate-relaxant method with regard to fulfillment of the stated demands has shown that

1 The method involves a much greater risk to the patient than local anesthesia plus pethidine method, because it requires a faultless functioning of a rather complicated technical apparatus, as well as an ideal, preferably firmly established cooperation of surgeon and anesthetist

Failure of a link in the procedure, *e g* , a block in the intravenous cannula, leakage or stoppage of the oxygen supply, trouble with the introduction of the bronchoscope, etc , may within a very short time cause complications, which in the dark room may be difficult to recognize and treat sufficiently early Experience will reduce the incidence of such complications, but the risk is always present We have seen no severe complications in our series, but a few times interruption was necessary due to technical difficulties involving a risk of hypoxia

2 The discomfort to the patient before and during the operation has been eliminated The discomfort following the intervention is probably somewhat greater than after local anesthesia supplemented by pethidine intravenously

3 The method yields very good conditions of operation, varying with the different modifications, *(vide infra)*

4 The method requires the assistance of a specialist in anesthesia

5 The restoration period is sufficiently short to render the method serviceable for out-patients

The various principles of oxygen supply and the techniques employed will be briefly reviewed

I Intermittent ventilation has been suggested by Churchill-Davison, among others Premedication with morphine and atropine is given After intravenous injection of 300 to 500 mg thiopental sodium and 60 to 75 mg succinylcholine iodide, hyperventilation is carried out for 30 to 60 seconds, with pure oxygen by means of mask and bag The vocal cords are thereafter sprayed with a local anesthetic (This has been done in all modifications of thiopental and succinylcholine anesthesia for bronchoscopy, because the relaxant effect vanishes prior to the effect of the barbiturate, so that without local anesthesia removal of the bronchoscope will often be followed by violent coughing and laryngeal spasm) The bronchoscope is then introduced, while at the same time the patient is ventilated with oxygen as often as possible, through a cut rubber tracheal catheter, passed so far into the Negus bronchoscope that it fits airtight

Oximetry shows that adequate oxygenation can be maintained in this way Such frequent ventilations in the bronchoscope are very inconvenient to the surgeon, but they can, to a great extent, be done during intervals of examinations, while the surgeon is changing optical instruments, or the like

The method takes a certain account of the Co_2 elimination, being, therefore, fit to be used over a fairly long period, providing curacite is constantly added for the purpose of maintaining apnea Supplementary doses of a barbiturate are rarely necessary, when the examination does not extend beyond 15 to 20 minutes

II The oxygen diffusion method has been proposed by Barth for bronchoscopy This method starts with ventilation, using oxygen for three to five minutes, without reinhalation of previously exhaled air (one-way-valve), whereby the nitrogen of the pulmonary air is replaced by oxygen Thereafter the barbiturate and relaxant are given, until complete apnea has occurred, which is maintained throughout the intervention During the bronchoscopy pure oxygen is conducted through a lateral tube in the bronchoscope with side holes

We found that, using this method, a constant maintenance of apnea is necessary, because otherwise the oxygen in the lungs will be "diluted" again with nitrogen, and the oxygen diffusion to the blood thus be reduced

Oximetry showed satisfactory values, providing the above requirements are met As, however, no Co_2 is eliminated by this procedure, apnea lasting more than 15 minutes involves a risk of Co_2 intoxication, cf Barth's own statement after pCo_2 measurements

III The insufflation method has been mentioned by Cheatle and Chambers, and others After administration of barbiturate and relaxant, the patient's lungs are ventilated two or three times with pure oxygen The bronchoscope is then introduced, and about one liter of oxygen per minute is conducted through a thin catheter passed down to the carina

The method was found suitable for very short examinations only (Cheatle and Chambers themselves stated five, or ten minutes at most), because the oxygenation is not reliably effective, and Co_2 is accumulated

IV The cuirass respirator method has been indicated by Toker, and Green and Coleman After administration of a barbiturate, a previously fitted respirator cuirass is placed on the patient's thorax and abdomen, and one makes sure that the respirator functions to satisfaction Then a relaxant is given, and it is controlled so that the respirator takes over the patient's respiration in a satisfactory way If so, the anesthesia can be continued as long as is desirable, affording ideal and undisturbed working conditions for the surgeon

In stocky, fat patients, as well as in patients with a stiff emphysematous thorax, it has been found difficult and in some cases impossible, to obtain sufficient change of air by this method

The apparatus being large and expensive, the method is usually employed in special wards

V *The ventilation bronchoscope* has been constructed by Mundnich and Hoflehner, and its use has been described by Kjaer, among others It is a Negus bronchoscope, provided with side holes at the distal end, so that both lungs are ventilated, even with the bronchoscope passed down into one bronchus The upper end can be closed by a glass pane Through a side inlet close to the upper end of the bronchoscope the patient can be ventilated with gases from an ordinary anesthesia machine

The patient's lungs can thus be ventilated through the bronchoscope during the whole period of bronchoscopy If airtight closing round the bronchoscope is desired, this can be obtained by manual pressing of the soft tissue above the larynx against the bronchoscope During prolonged bronchoscopy it is an advantage to be able to ventilate with a nitrogen oxide mixture, for instance, which allows reduction of the theopental sodium amount used and insures the patient's remaining asleep

When a telescope is used, the glass pane can be replaced by a rubber diaphragm, through which the telescope can be passed airtight Biopsy specimens cannot be taken simultaneously with the ventilation, but can be taken during a pause in this, especially if the patient has been hyperventilated in advance

The method is suitable for bronchoscopies where prolonged and undisturbed examination is desired, *e g*, in the teaching of diagnostic bronchoscopy, but it is unsuitable for bronchoscopies for the purpose of taking biopsy specimens

CONCLUSION

The practical result of our investigations, in connection with testing of the various methods, is that we still prefer local anesthesia supplemented by pethidine medication as standard method, especially in cases of old and very sick patients, where this method is supposed to involve the least risk A few patients with very brisk reflexes, or very nervous patients, in whom it has been found impossible to introduce the bronchoscope after local anesthesia plus pethidene, we prefer to anesthetize with barbiturate and relaxant, and use ventilation bronchoscope or, when biopsy has to be made, the cuirass respirator method In cases where anatomical conditions render examination in local anesthesia plus pethidine difficult, *e g*, a short stiff neck, long teeth, or the like, one must, however, be prepared for difficulties, also when employing the method with barbiturate and relaxant

SUMMARY

Early and modern methods of anesthesia for bronchoscopy have been reviewed, with reference to our experience in their use

Local anesthesia supplemented by pethidine intravenously has been found satisfactory, the method being fairly safe, easy to carry out, and yielding sufficiently good operative conditions in the great majority of patients

General anesthesia, using barbiturates and short-acting relaxants, yield ideal conditions of operation, but has been found to involve a greater risk to the patient

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CONCLUSION

The practical result of our investigations, in connection with testing of the various methods, is that we still prefer organs, particularly of the tongue *Voice* is produced by vibration of the vocal cords in the larynx In addition to these scientifically correct definitions, indicated as such by different typesetting, Webster explains other usages, including their interchangeable meaning as synonyms

The *voice* is one of the audible functions of the larynx, in particular of the vocal cords It is this act of phonation which makes human speech suitable for audible communication Expressed in the terms of the acoustic engineer, the voice represents the carrier wave In further analogy to the superimposition of the vibrations of speech or music by amplitude or frequency modulation of the radio carrier wave, the acoustic characteristics of the speech sounds or vocal timbers are added to the laryngeal voice by the articulatory movements of the speech organs

Following this technical example, we may compare the disorders of human communication to a disturbance in a radio station If the material to be broadcast is lacking, or if the performers fail for any reason, the diffusion of ideas by language or music will be deficient On the other hand, a failure in the acoustic system of microphones, cables, and amplifiers interferes with the proper modulation of the carrier wave, causing distortion or unintelligibility of singing and speech Finally, when the emitters of the carrier wave break down, no radio signal will be on the air to carry the audio frequencies produced by the performing speakers or singers It is this function of the human voice as a carrier wave for the modulation of speech sounds by articulation, and thus for the audible expression of thoughts, which will be considered in this paper

LARYNGEAL PATHOLOGY AND PHONATION

The voice can be impaired by many abnormal conditions of the larynx These may be *acute,* like infections, or *chronic,* like permanent changes in structure, further, they may be of *peripheral* origin, such as in laryngeal injury, or of *central* origin, as a result of some brain pathology Previously, one used to differentiate also between *organic* lesions, which would be recognizable by some changes in structure or

DYSPLASTIC DYSPHONIA

Minor Anomalies of the Vocal Cords Causing Persistent Hoarseness *†

GODFREY E ARNOLD, M D ,

New York, N Y

THE SIGNIFICANCE OF THE VOICE FOR COMMUNICATION

Speech is the fundamental prerequisite for the intellectual development and the social integration of man Due to its complex nature and to the manifold relations between speech and all phases of human activity the study of speech is shared by a large number of various sciences Ranging from acoustics to zoology, almost every science shows a well-defined interest in some problems of speech and advances the composite knowledge by specialized contributions

This variety of scholastic viewpoints produced many definitions of the terms dealing with speech Since scientific terminology is fully covered by the disciplines of linguistics, or speech psychology, there is no need to discuss it here, however, the common usage of these terms deviates from academic parlance Let us first clarify some of these discrepancies, particularly with regard to the concepts of language, speech, and voice

Language is defined in Webster's dictionary as the generic term, denoting in its most extended use any mode of conveying ideas Tongue is the Anglo-Saxon term for language, especially for spoken language Speech refers to oral communication and represents the faculty of expressing thoughts by audible words or articulate sounds

Articulation is the utterance of the elementary sounds of a language by the appropriate movements of the speech

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*Read at the First Symposium on Human Communication held at the National Hospital for Speech Disorders in April 1956

†From the Diagnostic Services (G E Arnold M D Clinical Director) of the National Hospital for Speech Disorders (Lynwood Heaver M D Director)

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remained isolated contributions to the then obscure correlation of structural peculiarities with losses of function, no general conclusions could be drawn After sufficient evidence had been accumulated it is now possible to arrive at a precise diagnosis in most of these cases

As usual, the case history assists in the differentiation of congenital and acquired conditions, and in addition, may present indications of hereditary or post-mutational types Routine otolaryngologic examination establishes the absence of infections or traumatic ailments If necessary, the customary laboratory and X-ray studies help to rule out general diseases More important is the corroboration of retarded physical maturation, hormonal imbalance, or constitutional debility by similar findings in other parts of the body When, finally, the finding of a congenital laryngeal abnormality can be correlated with the presenting vocal disorder, the diagnosis of dysplastic dysphonia, due to developmental hypoplasia of certain parts of the larynx, can be established with certainty

The psychological report is less helpful in such cases, for it is difficult to distinguish which part of the psychologic deviations, if present, are due to the secondary reaction of the individual to his disability, and which part may have been of primary contributing significance Sometimes, however, the psychologist reports infantilistic signs which then agree well with the concept of a psycho-somatic retardation of the emotional and physical development

MINOR LARYNGEAL MALFORMATIONS

Since the larynx is a single organ whose two halves pertain to the two sides of the body, it is easy to understand that the slightest irregularity in the development of either side will remain permanently visible in the form of asymmetrical configuration In fact, laryngeal asymmetry had been frequently described by the older authors An abundant variety of such observations had been analyzed in the encyclopedic review by Beck and Schneider (1926) They demonstrated that any part of the larynx may be the seat of congenital motility, and *functional* disorders, which would leave the structure intact while deranging the audible function

Similarly to other medical specialties one has lately recognized that no such artificial division can be made Sometimes marked structural abnormalities may be associated with excellent vocal function In other cases severe functional losses are present in a larynx which appears normal to the eye Between these two extremes are found the large majority of cases showing a combination of these two observations, moreover, the advances of bio-chemical and physiologic research demonstrate well-defined abnormalities in such diseases which were hitherto regarded as functional Schizophrenia is an example Hence, one prefers to classify diseases according to their etiologic causes, at least as far as presently distinguishable With regard to vocal pathology, increasing usage is made of an etiologic terminology, which has replaced the older symptomatologic classifications

DYSPLASTIC DYSPHONIA

In a large center for voice and speech disorders the exceptional cases are more frequently seen than in a regular clinic for ear, nose, and throat diseases For this reason, we encounter a relatively large number of patients whose hoarseness has been noticed since early childhood Others noticed the onset of their chronic vocal disability at the time of puberty Occasionally, such patients also report that some of their near relatives seem to have a similar disability It would, therefore, appear that there exist *hereditary, congenital,* and *post-mutational* types of chronic hoarseness

Laryngoscopic examination of these patients frequently reveals minor anomalies of the larynx While the well-known signs of the common laryngeal diseases are absent, one finds a great variety of structural abnormalities These affect the dimensions, proportions, relative positions and the bilateral symmetry of all laryngeal parts In previous years such findings were often reported in great detail Obviously, the authors hoped to correlate their visible findings with the audible disorders of the voice While those observations

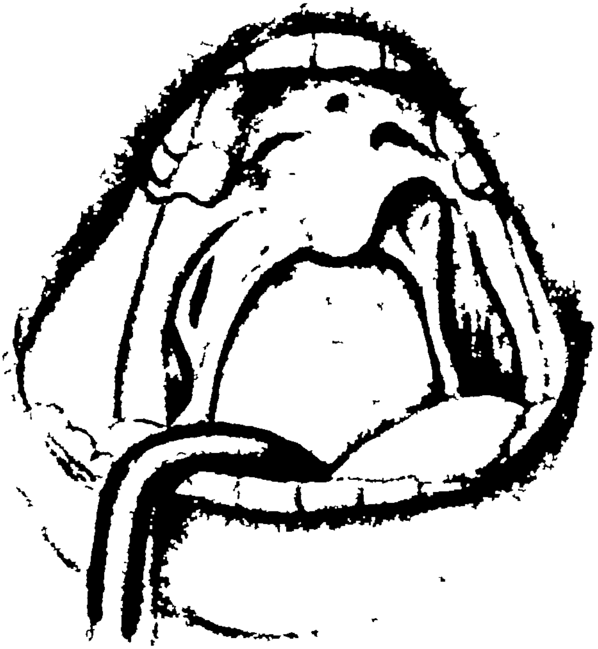

Fig 1 Congenital Malformation and Asymmetry of the Palate

congenital hypoplasia of the right vocal cord, one associated with hypoplasia of the right side of the tongue All three patients suffered from congenital dysplastic dysphonia This combination of laryngeal and lingual asymmetry had also been investigated by Motta In a monograph on the accessory chambers of the larynx, Bartels compared the human anomalies with the anatomical findings in primates and other mammals

Arnold (1947) gave a detailed analysis of a severe laryn-malformations Vocal disturbances are to be expected particularly when the vocal cords are affected Other regions may also disturb the voice or add pathologic noises to expiration One example is the pseudo-syrinx described by Jackson and Jackson This is a subglottic stenosis of the trachea which causes dyspnea and a crowing sound on coughing

As is well-known, the vocal cords perform the vibrations which produce the primary laryngeal voice Any irregularity in the length, breadth, thickness, specific weight, muscular development, position, insertion, motility and contractility, in short any asymmetry in the physical properties of the vocal cords must affect the acoustic qualities of the voice

Reker published, in 1938, a detailed phoniatric study of the correlation between minor laryngeal abnormalities and persistent vocal disabilities He came to the conclusion that some of these conditions are hereditary, others are simply present since birth and are called congenital, a third group appears after puberty, apparently being due to a maldevelopment of the infantile into the adult larynx, which would represent a developmental type of dysphonia Since four of his 18 cases showed additional asymmetry of the face, and since five cases revealed palatal asymmetry, he assumed the presence of a generalized constitutional debility of the peripheral organs of speech, at least in those cases Fig 1 shows a case of congenital palatal malformation

This combination of internal asymmetries of the larynx with other visible anomalies was also found by Tarneaud In his monograph on the laryngopathias (1944) he mentioned the combination of laryngeal displacement with spinal skoliosis In some cases the asymmetry of the thyroid cartilage may be felt by the palpating finger Luchsinger mentioned in his textbook (p 98) that these palpable asymmetries are a frequent finding in cases of constitutional weakness of the voice

Similar observations were made by Garde, whose recent case showed unilateral hyperplasia of many skeletal parts on the right side, associated with laryngeal asymmetry and dysplastic dysphonia Luchsinger reported three cases of more noticeable on one side Frequently it is associated with other laryngeal or oral asymmetries (see Fig 3)

This condition is rare as far as the general population is concerned In a specialized voice clinic, however, the sulcus of the vocal cord can be seen quite frequently At the National Hospital we observe a few cases among about 3,000 patients each year Arnold counted 12 cases among 1250 adults

TABLE I

NINE CASES OF LARYNGEAL ASYMMETRY FOUND AMONG 1250 SOLDIERS SUFFERING FROM DISORDERS OF VOICE AND SPEECH

1 Right cord lower than the left with hyperkinetic dysphonia
2 Right cord higher and broader than the left with congenital dysphonia.
3 Hypoplasia of the left cord with congenital dysphonia.
4 Congenital crossing of the arytenoids with secondary laryngitis and congenital dysphonia
5 Same with postmutational falsetto voice
6 Same with psychogenic hyperkinetic dysphonia
7 Same with vocalis insufficiency and habitual mixed dysphonia
8 Right ventricle of Morgagni wider than the left with developmental hypokinetic dysphonia
9 Right ventricle of Morgagni wider than the left with psychogenic hypokinetic aphonia.

(soldiers) who were referred for disorders of voice or speech These figures demonstrate again how statistics can be influenced by selective factors It is obvious that cases of chronic hoarseness tend to concentrate in clinics for the special care of vocal disorders

The vocal cord sulcus had been repeatedly noted by the older authors Kelemen quoted the autoptic findings of Denker, Giacomini (1892), and Grabert (1914), who studied the larynx of the gorilla and of various human races Salvi is usually credited with the first more complete description of the "sulcus vocalis" in 1901 Following the anthropologic ideas of his time, he considered the sulcus as a degenerative sign, allegedly more frequent among criminals Other authors, like Alézais (1906, 1912), described the condition as "double vocal cords" In 1906 Citelli undertook more extensive re-geal malformation with congenital dysphonia History, laryngoscopy, X-rays, anthropological report, and the vocal status led to the diagnosis of a laryngeal fracture during the complicated birth (see Fig 2) Similar to the classifications of other congenital malformations this case demonstrated the necessity of distinguishing between *constitutional* maldevelopments and acquired *connatal* malformations Hence, there exist cases of connatal traumatic dysphonia His nine other observations of laryngeal asymmetry were published

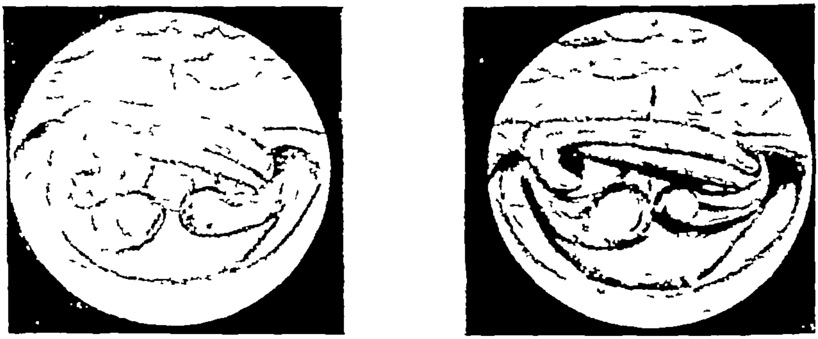

Fig 2 Connatal Malformation of the Larynx due to Laryngeal Fracture by birth injury

in 1948 Table I shows the various forms of asymmetry, and their association with several types of dysphonia, the majority being of congenital origin

VOCAL CORD SULCUS AND DOUBLE VOCAL CORDS

The vocal cord sulcus is a fine longitudinal furrow on the medial edge of the vocal cord It may extend over the entire length of the cord, or may be limited to a segment of variable length, its depth is also variable, ranging from a faint line to a deep partition of the cord In the latter case it divides the cord into two portions, an upper or lateral lip, and a lower or medial lip This is then called a double vocal cord There may even be an accessory ventricle behind a very deep sulcus The sulcus may be unilateral, bilateral, or may be more noticeable on one side Frequently it is associated with other laryngeal or oral asymmetries (see Fig 3)

This condition is rare as far as the general population is concerned In a specialized voice clinic, however, the sulcus of the vocal cord can be seen quite frequently At the National Hospital we observe a few cases among about 3,000 patients each year Arnold counted 12 cases among 1250 adults

TABLE I

NINE CASES OF LARYNGEAL ASYMMETRY FOUND AMONG 1250 SOLDIERS SUFFERING FROM DISORDERS OF VOICE AND SPEECH

1 Right cord lower than the left with hyperkinetic dysphonia
2 Right cord higher and broader than the left with congenital dysphonia
3 Hypoplasia of the left cord with congenital dysphonia
4 Congenital crossing of the arytenoids with secondary laryngitis and congenital dysphonia
5 Same with postmutational falsetto voice
6 Same with psychogenic hyperkinetic dysphonia
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The first observation on a patient was made by Lautenschlager (1912) He also recognized that the hoarseness was due to the incomplete closure of the glottis, therefore, he suggested that the insufficiency be corrected by the intralaryngeal injection of paraffin, according to the then new method of Brunings In Oertel's case of 1912, an acute inflammation and swelling of the vocal cords temporarily improved the hoarseness which showed again that the dysphonia in a case of vocal cord sulcus was primarily due to the bowing glottis

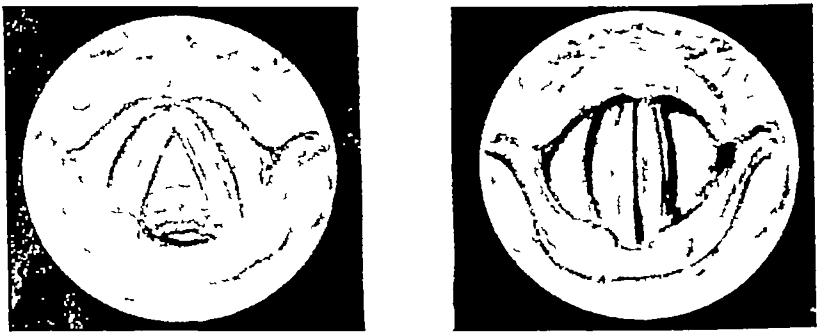

Fig 3 Congenital Asymmetry of the Larynx with Sulcus on Left Cord and Hypoplasia of the Right Ventricular Fold

In 1928 Berger submitted the first phoniatric and stroboscopic analysis of the congenital dysplastic dysphonia due to vocal cord sulcus, or double vocal cords Again, he noted the incomplete closure of the glottis More cases were subsequently described by Van Caneghem (1928), Fornai (1936), Tarneaud (1944), or Delaini and De Stefani (1952) One of their four cases showed hereditary tendencies The largest number of cases was seen by Arnold who, in 1948, reported 12 observations The combination with further laryngeal and oral anomalies in these cases is shown on Table II

For a time some authors disagreed on the possible etiologic factors Bilancioni observed in 1923 the development of a tuberculous ulcer within a preexisting sulcus Kelemen further quoted Spiess (1908), who saw the development of a longitudinal scar as a residue of a healed vocal cord gumma Another opinion in favor of the tuberculous origin was voiced by Van Caneghem (1928), while Garel (1922) believed in a shrinking atrophy following chronic laryngitis If one considers the frequency of tuberculosis, syphilis, or chronic laryngitis at the time of these observations, a coincidental combination of the congenital sulcus with such acquired granulations would not be surprising

TABLE II

12 CASES OF VOCAL CORD SULCUS FOUND AMONG 1250 SOLDIERS SUFFERING FROM DISORDERS OF VOICE AND SPEECH

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1 Sulcus on right cord prolapse of the left arytenoid with congenital hypokinetic dysphonia
2 Sulcus on both cords hornlike elongation and phonatory crossing of both corniculate tubercles (similar to Blumenfeld's case reproduced by Beck and Schneider on their p 42[9]), absence of both cuneiform tubercles with dysphonia ventricularis
3 Sulcus on both cords with habitual hyperkinetic dysphonia
4 Sulcus on both cords with congenital hypokinetic dysphonia
5 Sulcus on both cords with incomplete mutation of the voice (developmental dysphonia)
6 Sulcus on both cords with developmental dysphonia and dysphemia (stuttering)
7 Sulcus on left cord with developmental dysphonia
8 Sulcus on left cord with habitual mixed dysphonia
9 Sulcus on left cord deeper than the right asymmetry of Morgagni's ventricles (the right wider than the left) vocalis insufficiency with congenital hypokinetic dysphonia and lisping (see Fig 3)
10 Sulcus on left cord deeper than the right contact ulcer right vocalis insufficiency anterior ventricular hyperkinesis with congenital hypokinetic dysphonia
11 Sulcus on left cord deeper than the right palatal asymmetry with developmental dysphonia
12 Sulcus on left cord with diphtheric vagus paralysis on the right.

search and found further parallels in the comparative anatomy of animals. He coined the term "sulcus glottideus" and claimed to have found it in every second larynx dissected for this purpose. Sometimes the sulcus was barely visible with the naked eye. Further autopsy findings were reported by Hajek (1928), Demel (1928), Kelemen (1929), and by Frank and Malev (1939).

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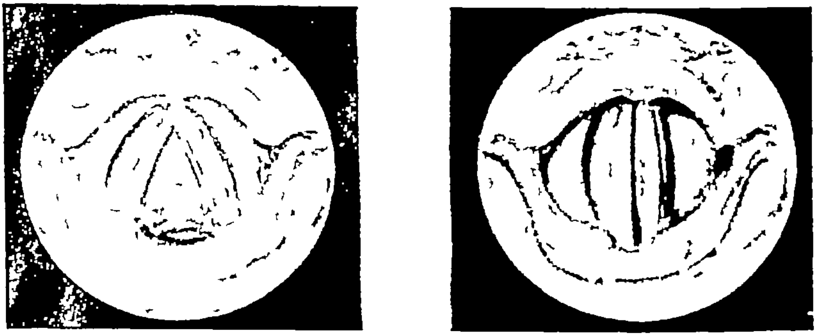

Fig. 3. Congenital Asymmetry of the Larynx with Sulcus on Left Cord and Hypoplasia of the Right Ventricular Fold.

In 1928 Berger submitted the first phoniatric and stroboscopic analysis of the congenital dysplastic dysphonia due to vocal cord sulcus, or double vocal cords. Again, he noted the incomplete closure of the glottis. More cases were subsequently described by Van Caneghem (1928), Fornai (1936), Tarneaud (1944), or Delaini and De Stefani (1952). One contraction of the external strap muscles, or constriction of the supraglottic resonance chambers Habitual hyperkinetic disorders are thus superimposed on the congenital hypokinesis of the vocal cords, producing various combinations of vocal disfunction

Treatment is rather difficult Since the observations of Lautenschlager and Oertel it is well-known that the direct cause of the hoarseness consists of the hypoplasia of the vocalis muscles Because these hypoplastic, asymmetrical, and possibly divided cords do not completely close on phonation, the voice is always accompanied by an escape of air This addition of non-vibrating air to the voice sound is heard as hoarseness Consequently, any surgical attempt at improvement would have to increase the closure of the glottis I intend to follow Réthi's procedure, who corrected the state of myopathic paresis of the vocalis muscles by injecting vaseline into the bowing cords The cartilage paste recommended in another publication (Arnold) for the compensation of adductor paralysis appears suitable also for a congenitally bowing cord Messerklinger and Doubek described the successful correction of a bowing cord due to unilateral congenital sulcus by intra-cordal injection of paraffin by the Brunings method

Vocal rehabilitation by appropriate voice therapy should always be tried In any case one can improve the condition by eliminating the secondary parakinesias so that the patient may learn how to use his voice as well as his anatomical condition will permit Unfortunately, it has to be admitted that the amount of progress is always limited At the present time such voices cannot be greatly improved It is, therefore, most important to advise these patients not to choose an occupation with heavy or specialized demands on the voice Early recognition of the condition is the best service we can presently render to these patients All authors share this prognostic reservation

REPORT OF A CASE

Case No 71940, Pearl C a white unmarried female age 18, was first seen on February 1 1950 She complained of chronic hoarseness since earliest childhood No other relative has any voice trouble She

All recent authors are in accord with the original discoverers that the vocal cord sulcus is a congenital malformation Jackson and Jackson, who saw four cases of "supernumerary cords," called it a malformation of atavistic origin Many authors referred to the normal presence of the sulcus in various animals, ascribing a regressive significance to its occurrence in man (Kelemen, Tarneaud, Delaini and De Stefani, etc) The latest contribution to this interpretation was made by Sberinini in 1954 Evidence for the normal presence of a sulcus in animals can be found in the papers of Albrecht (1896), Wilson (1910), and particularly by Nemai (1912, 1926) The latter described double vocal cords, divided by a sulcus, in many species deer, giraffe, antelope, swine, gibbon, etc In accordance with previous authors, he found these accessory cords most noticeable in primates It is interesting to note that he considered the development of these accessory cords below the true vocal cords of the gibbon as unfavorable for the vocal abilities of this species According to Kelemen (1949) the reduplication of the vocal cords is particularly prominent in the chimpanzee larynx He believes that the double cords are partly responsible for the double tones frequently heard in the voice of the chimpanzee

SYMPTOMS OF DYSPLASTIC DYSPHONIA

When listening to this type of voice, one is impressed by a peculiar hollow and unpleasant quality It is difficult to describe it in words, but it reminds one of the sound made by a broken pot It seems as though the two cords were out of tune There is a constant breathy quality due to the excessive escape of air between the bowing cords Hence, phonation time is short and the volume is weak The average speaking pitch is often too high, apparently because the high tones are usually clearer This is due to the bowing glottis, which is physiologic for the male falsetto tones, and, therefore, does not disturb the high tones as much as the low tones Moreover, the patients tend to abuse their weak voices by faulty attempts at compensation Instead of exploiting all reserves of projection and resonance, they try to overcome their disability by increased muscular efforts This leads to various parakinesias, such as phonatory elevation of the larynx, over-

CONCLUSIONS

The voice is an integral part of the human organs of communication It represents the carrier wave on which are superimposed the modulations of the laryngeal voice sound by the articulatory movements of the speech organs Serving this specific function, the voice should not be confounded with the other components of communication The terms articulation, speech, and language, describe specific aspects of oral communication and cannot be used interchangeably

Laryngeal pathology may disturb the voice in many ways Contrary to the old idea of distinguishing organic and functional vocal disturbances, one now attempts an etiologic classification of the various dysphonias

Dysplastic dysphonia refers to a group of chronic vocal disabilities due to minor anomalies of the larynx They may be of hereditary, congenital, and connatal origin, or they may appear as a result of faulty laryngeal maturation during puberty

The minor laryngeal malformations are characterized by great diversity Their salient feature is an asymmetrical development of the two laryngeal halves, particularly of the vocal cords

A special condition of congenital laryngeal anomaly appears in the form of the vocal cord sulcus If deep enough, it creates the impression of reduplication of the cords All recent authors regard this condition as a congenital anomaly of atavistic or regressive origin

The symptoms of dysplastic dysphonia are well understood and do not present any diagnostic difficulties Regrettably, the same cannot be said regarding treatment One of our cases illustrates this general experience In the future it will be worth while to apply the surgical principles of vocal cord injections Favorable results were shown by Réthi (vaseline), Messerklinger and Doubek (paraffin), and Arnold (cartilage paste) had always enjoyed good health and does not remember any unusual upper respiratory infections or allergies Menstruation is uncomplicated and regular Several previous examinations had reportedly been negative

General appearance A slender asthenic, normally developed girl of good intelligence with pleasant manners and an apparently calm temperament No signs of emotional disturbance No signs of anemia or other disease

Nose and nasopharynx The mucous membranes are unusually thin, pale and delicate The turbinates are small and the passages open No abnormal secretion no respiratory obstruction

Mouth The lips teeth, gums tongue and the palate appear normal Tonsils are absent The oral mucosa is unusually delicate and pale

Ears and tubes Very delicate membranes, no pathology

Larynx Small but symmetrical All parts are very small and delicately built The mucosa is thin and pale Gross motility is normal The vocal cords are white thin and narrow a longitudinal fine sulcus along the medial border of either side gives the impression of double vocal cords The entrances to the ventricles are very wide During phonation the bowing cords close incompletely leaving an oval glottal chink wide open The vibrations appear to take place between the lower segments of the cords

Voice Very hoarse, breathy and weak Average speaking pitch between a d^1 (220 294 cps) Vocal range g c^2 (196 523 cps), no differentiation of registers, the higher tones sound definitely better Phonation time Vowel O on tone c^1 7 8 sec (normal 20 sec) Marked strain of the external laryngeal muscles is noticeable during phonation

Speech No noticeable disorder of articulation, diction or sentence construction

Diagnosis Constitutional hypoplasia of all upper respiratory membranes congenital bilateral sulcus with reduplication of vocal cords, congenital hypoplasia of the thyroarytenoid muscles, dysplastic dysphonia hypokinetic type

Treatment advised Attempt at vocal rehabilitation by improving resonance, projection and enunciation two sessions per week

Progress notes October 4 1950 no change in objective findings but patient believed to be considerably improved December 13, 1950 subjective satisfaction continues August 15, 1951 the voice continues to sound hoarse breathy and shrill October 29, 1951 no change in the bowing of the double cords May 26 1952 although the patient appears very satisfied her voice is as hoarse breathy and harsh as before She left the hospital after having attended more than 200 therapy sessions

In October 1952 she was seen in Bellevue Hospital where we made essentially the same findings and recommendations Apparently the subjective improvement had not been permanent In March 1954 she appeared at the New York Eye and Ear Infirmary, where her congenital vocal disability was interpreted as 'a hysterical speech defect"

Discharge summary A case of congenital dysplastic dysphonia had been observed and treated for about four years In accordance with all previous observations no improvement could be achieved An interesting feature in this case was the marked hypoplasia of all visible mucous membranes Finally, the vibrations of the cords seemed to be concentrated on the lower portions of the double cords In contradistinction, most of the previous observers had noted the vibration of the upper segments

CONCLUSIONS

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SUMMARY

The well-known definitions of the various aspects of human oral communication are recalled The basic function of communication is human phonation It may be disturbed by many abnormal conditions, including congenital anomalies of the larynx These malformations may affect all parts of the voice organs, and are particularly harmful to the voice if they disturb the symmetry and fine coordination of the vocal cords One discrete cause of such dysplastic dysphonias is seen in the well-known condition of double vocal cords This disability is described in detail and illustrated by a typical case

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Gratitude is expressed to George Kelemen, M D, for his aid in the compilation of the bibliography

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POST GRADUATE COURSE IN RHINOPLASTY, RECONSTRUCTIVE SURGERY OF NASAL SEPTUM AND OTOPLASTY

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AURAL-HARMONIC AND BONE-CONDUCTION THRESHOLDS IN THE EVALUATION OF COCHLEAR RESERVE IN CLINICAL OTOSCLEROSIS *†

PHILLIP A YANTIS, Ph D ,
and
JOHN E MAGIELSKI, M D ,
Ann Arbor, Mich

It has been generally accepted for some time that the prognosis for a significant improvement of hearing sensitivity due to operative intervention in the ear with a loss due to clinical otosclerosis depends to a great extent on the adequacy of cochlear function The primary question to be answered by audiologic examination in these cases is this Is the function of the cochlear structures sufficiently normal, as determined by pre-operative functional testing, that significant restoration of hearing sensitivity can be expected in the event of successful operative negation of the conductive impediment due to otosclerosis?

In attempting to test the adequacy of cochlear function, it is important to employ tests that will not be influenced significantly by any physiological abnormality of the middle ear The most widely used procedure in developing an operative prognosis in these cases has been to compare the pure-tone thresholds obtained by air and by bone conduction, sometimes referred to as the "air-bone gap" A number of investigators have attached a great deal of importance to the bone threshold in relation to judging post-fenestration hearing sensitivity

Shambaugh[1] suggested that those ears that are ideal for

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*An adaptation of this paper was presented at the 32nd Annual Convention of the American Speech and Hearing Association Chicago November 1956

†From the Department of Otolaryngology and the Physiological Acoustics Laboratory University of Michigan Medical School This research was supported in part by the Research and Development Division Office of the Surgeon General Department of the Army under Contract DA-49-007-MD-634

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fenestration have a bone threshold within the normal range at 512, 1024, and 2048 cps Those suitable but not ideal have abnormal bone-conduction sensitivity at 2048 cps, but normal thresholds at the other two frequencies He classified those with a bone-conduction audiogram slightly below normal for two or all three of the above frequencies as having a limited and guarded prognosis In a like manner, Kos and Reger[2] defined three classes of patients as determined by the relation between pre-operative bone and air thresholds Those in Class I, with the best prognosis for improvement by fenestration surgery, show a bone acuity not exceeding an average loss of 15 db for the frequencies 500, 1000 and 2000 cps The second class of patients has an average bone acuity exceeding 20 db, but with at least a 30 db gap in the three frequencies The third class, and that group with the poorest prognosis, is made up of those with a bone acuity exceeding an average loss of 20 db at the three frequencies Shambaugh and Carhart[3] mentioned that an air-bone gap of less than 35 db is a contraindication for fenestration They believed that the ideal candidate has a maximum gap of 55 to 60 db and a bone curve within 5 db of the normal zero line

Pick[4] recently listed what he thought are indications for stapes mobilization, and again the loss by bone conduction was emphasized, as well as the size of the air-bone gap, however, his indications for favorable prognosis were not as conservative as those proposed by other writers in relation to the fenestration procedure

Personal observations of pre-operative bone-conduction sensitivity measures in otosclerotic ears, coupled with results obtained by other investigators, have led the authors to have certain reservations regarding the validity of air-bone comparisons alone in the judgment of cochlear reserve It is the purpose of this paper to outline briefly the problems in bone-conduction technique and interpretation, and to discuss the application of a comparatively new technique to the evaluation of cochlear reserve the aural-harmonic (aural-overload) test *

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*This technique has been referred to as both the aural-harmonic test[24-26] and the aural-overload test[19-22] The former title is employed in this paper in order to promote consistency in terminology

BONE-CONDUCTION TESTING

Two of the important parameters in bone-conduction measurement are those of variations in the pressure of the vibrator against the skull, and individual differences in compliance of skin tissue between the vibrator and the mastoid process Goodhill and Holcomb[5] found that even when the pressure of the receiver is constant at 400 grams, individual tissue variations may cause an error of 5 db or more in sensitivity They mentioned that bone-conduction results may be "contaminated" by such factors as air-borne sound being radiated by the bone-conduction unit, cartilage conduction from the vibrator to the tympanic membrane, and translational excitation of the ossicular chain due to inertia Carhart[6] discussed other problems, such as faulty audiometer calibration, improper masking techniques, etc At least some of these latter factors exist in any pure-tone audiometric situation, and can be effectively eliminated through careful precautions on the part of the examiner

Even though the above criticisms are of importance, they are somewhat overshadowed by one particular phenomenon peculiar to bone-conduction testing in ears with stapes ankylosis The restriction of stapedial motion relative to the skull seems to decrease substantially the bone-conduction sensitivity in the middle frequencies *in and of itself,* in many cases, even though the anatomic structure of the cochlea and its inherent physiological characteristics are apparently normal This observation was noted by Smith[7] when he found such restrictions in a series of cats in which stapedial motion had been mechanically reduced Mean sensitivity to bone-conduction stimulation was lowered 15 db at 500 cps, 20 db at 700 cps, 16 db at 1000 cps, 9 db at 1500 cps and 4 db at 2000 cps after stapes fixation

Various investigators have confirmed this phenomenon in pre- and post-operative examinations of a number of patients with otosclerosis Table I shows the post-operative mean changes in bone-conduction thresholds in a total of 203 patients tested by six investigators Woods[13] found that 90 per cent of 46 cases showed bone-conduction improvement after fenestration and, in five other patients, he found an average increase of 14.2 db in the speech frequencies.

On the basis of such evidence, Carhart[3,6] proposed that pre-operative bone-conduction thresholds may be corrected 5 db at 512 cps, 10 db at 1024 cps, 15 db at 2048 cps and 5 db at 4096 cps, to predict post-operative bone-conduction sensitivity more accurately. Although this concept is important in emphasizing the changing character of bone-conduction sensitivity following surgery, the exact formula for each frequency cannot always be relied upon in an individual case. This fact is amplified in studying not only the mean changes in bone conduction found by other investigators in terms of the apparent discrepancies in discrete thresholds from one group to another (see Table I), but, more significantly, in viewing the results obtained in individual cases. It is also necessary to keep in mind that Carhart's observations were made on ears that had undergone fenestration surgery. Because of the obvious differences in the concomitant anatomic and physiological characteristics of the middle ear following the fenestration operation, as compared to stapes mobilization surgery, it is apparent that complete reliance cannot be placed on the "otosclerotic notch" principle when stapes mobilization is the procedure of choice, until further research is conducted.

TABLE I

MEAN CHANGES IN BONE CONDUCTION SENSITIVITY FOLLOWING FENESTRATION SURGERY IN A TOTAL OF 203 EARS

Author	Reference No.	No. Ears	Bone-Conduction Improvement—Decibels 500 cps	1000 cps	2000 cps	4000 cps
Henner	8	72	2.5	8.7	8.2	7.5
Juers	9	28	3.0	4.2	13.0	
McConnell and Carhart	10	58	1.4	6.5	8.5	4.2
Nilsson	11	10	6.0	7.0	14.0	4.0
Sohoel*	12	35	15.0	12.0	11.0	–2.0

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*The purpose of this recent investigation was to emphasize the changing character of bone sensitivity immediately following surgery. The thresholds quoted here were made three weeks post-operatively and were of a stable character. The bone-conduction vibrator was applied to the forehead of all the patients tested in this particular study and the ear not under test was masked.

Some of the physiological concepts that must be kept in mind in attempting to evaluate the bone threshold in losses due to otosclerosis will be reviewed and discussed later

Because the accuracy of sensitivity thresholds made by bone conduction in the otosclerotic ear is at least questionable with respect to the judgment of cochlear reserve, bone-conduction sensitivity was compared with measurements obtained on the aural-harmonic test pre- and post-operatively The latter procedure employs an entirely different physiological principle than does bone-conduction testing, and purports to be a direct measure of cochlear function

THE AURAL-HARMONIC TEST

The aural-harmonic (aural-overload) test is based on the observation that if a tone is presented to the ear at a sufficiently high intensity, the structures of the organ of Corti will not respond with normal fidelity[15, 16] This phenomenon is known as amplitude distortion or, more descriptively, aural overload It has been found that not only is this distortion process a cochlear phenomenon,[17] but that, in the event the structures of the inner ear are damaged or are not functioning normally, the sensation level at which distortion begins to appear is lower than normal[18 19 20 21, 22 25 26]

To achieve the sensation level at which distortion occurs, some method must be employed by which the subject can communicate the emergence of this phenomenon to the examiner This may be done by employing a variation of the classic exploring-tone method[23] A pure tone (in this case 1000 or 2000 cps) is introduced into the ear, and is gradually raised in intensity until distortion first appears This tone is referred to as the fundamental When distortion occurs, the amount of acoustic energy which cannot be linearly transmitted by the cochlear structures involved is converted into harmonics of the fundamental tone, however, the untrained subject usually cannot hear these harmonics in his own ear because of the comparative loudness of the fundamental tone In consequence, the exploring-tone method is employed to enable the subject to report the presence of the harmonics in the form of a sensation of beats after fenestration and, in five other patients, he found an average increase of 14 2 db in the speech frequencies

On the basis of such evidence, Carhart[10] proposed that pre-operative bone-conduction thresholds may be corrected 5 db at 512 cps, 10 db at 1024 cps, 15 db at 2048 cps and 5 db at 4096 cps, to predict post-operative bone-conduction sensitivity more accurately Although this concept is important in emphasizing the changing character of bone-conduction sensitivity following surgery, the exact formula for each frequency cannot always be relied upon in an individual case This fact is amplified in studying not only the mean changes in bone conduction found by other investigators in terms of the apparent discrepancies in discrete thresholds from one group to another (see Table I), but, more significantly, in viewing the results obtained in individual cases It is also necessary to keep in mind that Carhart's observations were made on ears that had undergone fenestration surgery Because of the obvious differences in the concomitant anatomic and physiological characteristics of the middle ear following the fenestration operation, as compared to stapes mobilization surgery, it is apparent that complete reliance cannot be placed on the "otosclerotic notch" principle when stapes mobilization is the procedure of choice, until further research is conducted

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McConnell and Carhart	10	58	1 1	6 5	8 5	1 2
Nilsson	11	10	6 0	7 0	11 0	1 0
Söhoel*	12	35	15 0	12 0	11 0	-2 0

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When a 1000 cps fundamental tone is introduced into the ear, for example, an exploring tone of 2004 cps is also led to the ear at an intensity level slightly less than the level of the fundamental When the intensity of the fundamental is sufficiently high to produce aural distortion, the subject will hear four beats per second in the background of the fundamental These beats are produced through the interaction of the 2004 cps exploring tone with the 2000 cps second harmonic of the fundamental generated in the inner ear When these beats are heard, the intensities of both the fundamental and the exploring tone are equally reduced until the subject no longer hears the beats The intensity of the fundamental at which these beats are first detected is called the aural-harmonic, or aural-overload, threshold, and the number of decibels between sensitivity threshold and the detection threshold of the aural-harmonic is the linear range of hearing at

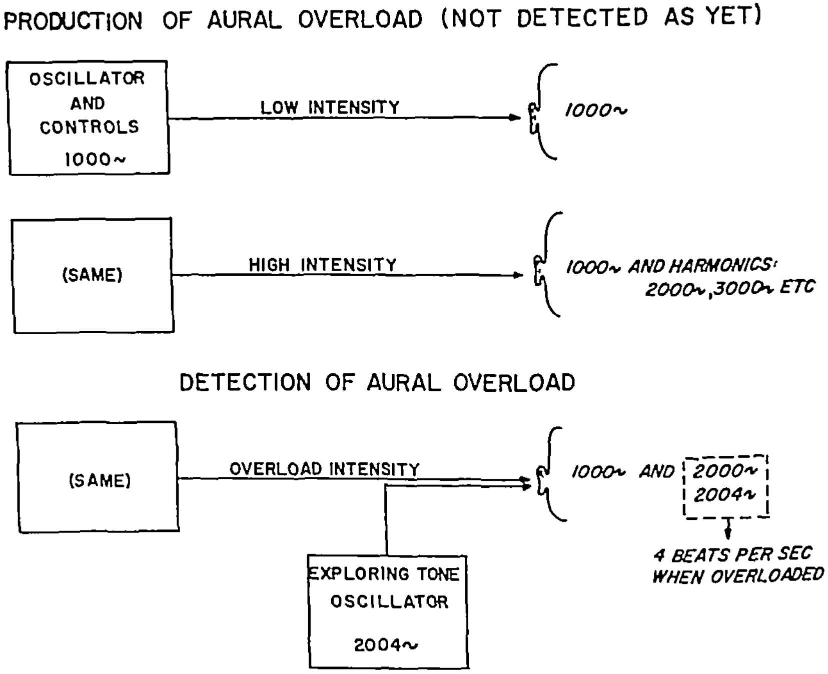
PRODUCTION OF AURAL OVERLOAD (NOT DETECTED AS YET)
OSCILLATOR AND CONTROLS 1000~
LOW INTENSITY
1000~
(SAME)
HIGH INTENSITY
1000~ AND HARMONICS: 2000~, 3000~ ETC
DETECTION OF AURAL OVERLOAD
(SAME)
OVERLOAD INTENSITY
1000~ AND
2000~
2004~
4 BEATS PER SEC WHEN OVERLOADED
EXPLORING TONE OSCILLATOR 2004~

Fig 1 Schematic diagram of the technique employed in detecting the aural-harmonic (aural-overload) threshold

the particular fundamental frequency being tested A simple illustration of the procedure involved in this test is given in Fig 1

Lawrence and Yantis[19] found, in over 130 normal ears, that the mean range at 1000 cps was 52 db and 57 db at 2000 cps Means obtained in abnormal ears were published in the last-cited study, but since that time a larger number of cases tested in this clinic have been added to the original data to give the mean values listed in Table II *

TABLE II

MEAN AURAL-HARMONIC THRESHOLDS OBTAINED IN NORMAL AND ABNORMAL EARS

Category	1000 cps No Ears	1000 cps Mean (db)	1000 cps Stand Dev (db)	2000 cps No Ears	2000 cps Mean (db)	2000 cps Stand Dev (db)
Normal Ears	145	52	13	133	57	17
Middle-ear Pathology*	34	45	6	36	48	8
Cochlear Pathology	33	13	9	40	19	11

*These figures do not include the aural-harmonic data obtained in the ears reported in this study

Three investigators, employing different fundamental and exploring-tone frequencies, have reported mean thresholds closely comparable to those of Lawrence and Yantis Sokolowski,[24] using a 500 cps fundamental tone applied by air conduction and a 1003 cps exploring tone by bone conduction, found harmonic thresholds in normal ears from 45 to 50 db above the fundamental-tone threshold In losses of a conductive type, the threshold was essentially the same in sensation level, however, in perceptive losses with recruitment, Sokolowski found the aural-harmonic threshold to be only slightly higher than the intensity of the 500 cps fundamental tone, providing the extent of the loss exceeded 45 to 50 db Opheim and Flottorp,[25] using fundamental frequencies of 250 and 500 cps, found no difference between normal harmonic thresholds and those in ears with conductive losses, but markedly restricted ranges in 70 out of 73 ears with recruitment were recorded They also found the test very helpful in the differential diagnosis of Meniere's disease [26]

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*Through a mathematical error the means and standard deviations of harmonic thresholds measured at 1000 cps in the 17 ears with cochlear involvement were incorrectly stated in the article by Lawrence and Yantis[19] and in the paper by Yantis[20] In both of these publications the mean range of linearity between audibility threshold and harmonic threshold was given as 24 db and the standard deviation as 14 db The correct calculations are a mean of 12 db and a standard deviation of 7 db This correction is incorporated in the data of Table II

Since the aural-harmonic test employs the air-conduction pathway rather than the osseous route, it seems to be a measure of cochlear function not significantly influenced by the physiological status of the middle ear, and may hold some promise of being a comparatively *quantitative* measure of cochlear function Accordingly, this procedure was compared with bone-conduction testing pre- and post-operatively with respect to the relative stability of the two tests under conditions of stapes ankylosis and improved hearing after surgical intervention

PROCEDURE

The nineteen patients tested in this study were examined in the Department of Otolaryngology, University Hospital Each patient was given a complete pure-tone audiometric examination at least three times before the aural-harmonic test, with at least a one-month interval between each examination The audiogram accepted as each patient's pre-operative threshold pattern was an average of the three audiometric examinations conducted

Pure-tone audiometric and aural-harmonic tests were repeated no less than one-and-one-half months post-operatively in those patients who submitted to fenestration surgery, and when necessary, after stapes mobilization This was done to reduce to a minimum any possibility of the contamination of sensitivity measures by labyrinthine after-effects of surgery (see Sohoel[12])

Pure-tone audiometric tests by air and bone conduction were carried out, using a calibrated Maico H-1 clinical audiometer Traditional audiometric techniques were employed, including the use of masking when necessary All tests on each subject were made with the same equipment and technique, and by the same examiner

In attempting to reduce maximally the effects of the possible paramaters in bone-conduction technique outlined earlier, the following points were consistently followed in testing the patients used in this study

1 Calibration of the bone-conduction vibrator was carried out, using Carhart's method of air and bone comparisons in normal ears and ears with a moderate pure perceptive loss[6]

2 During all bone-conduction tests, the vibrator was held against the skull by a headband attached on the opposite side of the head to an earphone The latter was placed over the external meatus of the ear not under test in all patients, whether masking was employed in the opposite ear or not No means of keeping the pressure of the vibrator constant for all the ears tested was used, other than that of securing the vibrator as tightly as possible without causing pain or discomfort

3 In all cases, the exact position of the vibrator post-auricularly was determined by ascertaining the best position to obtain the lowest sensitivity threshold for a 1000 cps tone The position decided upon was permanently used for all frequencies tested on any one ear Repositioning was always carried out in subsequent sessions

4 When masking was employed, careful attention was given to the intensity of the complex-noise masking signal to eliminate the possibility of trans-cranial conduction of the noise

Aural-harmonic tests were carried out with carefully calibrated equipment especially designed for clinical use * A detailed account of the original laboratory equipment used in previous experimentation is fully described elsewhere.[18, 19] Very briefly, the technique employed in clinical testing was as follows

1 The patient is instructed that he will hear a loud, steady tone, and that he should listen in the background of that tone for a wavy, or beating sensation If he hears only a qualitative sensation of steadiness, he is asked to say "steady" after listening briefly to the tone If he hears a beating sensation, he is requested to say "beat" Variations on this basic set of instructions are sometimes made if there is any doubt that the patient does not understand

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*For the harmonic-detection measurements made in this study a clinical instrument designed and manufactured by Maico Electronics Inc was employed. The inherent distortion characteristics of the fundamental-tone oscillator were found to be very low the second harmonic of the two fundamental tones was more than 60 db below the acoustic level of the fundamental This factor is of course extremely important in order to eliminate the possibility of intermodulation distortion occurring in the stimulus itself [illegible]

2 The fundamental tone (either 1000 or 2000 cps) is then set to an entensity up to 70 db above audibility threshold for that tone The exploring-tone frequency is then made to differ from the second harmonic of the fundamental by approximately 4 cps , and is originally adjusted to be 10 db below the intensity of the fundamental tone These adjustments are made without stimulation of the ear under test

3 The two tones are then mixed and presented to the ear being tested In most cases the patient hears beats with only a slight adjustment of the exploring-tone intensity If beats are not readily perceptible, then various techniques may be employed

a The levels of both tones may be raised equally

b The level of the exploring tone may be varied

c The exploring tone may be turned off and on for a short time

d Combinations of the above may be employed

4 Upon hearing beats, the levels of both tones are commonly attenuated until the subject no longer hears the beats If beats are still not heard after decreasing the level of the exploring tone, the level of the fundamental tone is recorded and considered to be the aural-harmonic threshold The linear range is determined by substracting the audibility threshold for the fundamental tone from the intensity above normal audiometric zero at which the harmonic threshold was obtained

5 The linear range is checked by carrying out the test from below the harmonic threshold previously obtained

For the purposes of this study, a range from audibility threshold to aural-harmonic threshold at either 1000 or 2000 cps that is less than 35 db (approximately one standard deviation from the mean in normal ears or in cases of conductive loss) is taken as indicative of abnormal cochlear function

RESULTS

The sex, age, ear operated upon and the type of operation performed are identified for each case in Table III Ten males and nine females were examined in this study, the age range was from 21 to 52 years, with a mean of 35 years A total of 20 ears was tested, since Case 14 was operated upon bilaterally Data were completely gathered on 19 ears at 1000 cps, and 17 ears at 2000 cps Of the 20 ears tested, the fenestration operation was performed on seven and stapes mobilization was carried out on the remaining 13

TABLE III

IDENTIFYING DATA ON EACH OF THE NINETEEN PATIENTS (TWENTY EARS) TESTED

Case No	Sex	Age	Ear	Operation
1	F	28	Lt	Fenestration
2	M	29	Lt	Fenestration
3	M	52	Rt	Fenestration
4	F	21	Lt	Stapes Mobilization
5	F	41	Lt	Stapes Mobilization
6	F	29	Rt	Fenestration
7	F	34	Rt	Fenestration
8	F	35	Rt	Stapes Mobilization
9	M	52	Lt	Stapes Mobilization
10	M	31	Rt	Stapes Mobilization
11	F	29	Lt	Fenestration
12	F	52	Lt	Stapes Mobilization
13	F	43	Lt	Stapes Mobilization
14	M	39	Rt	Stapes Mobilization
			Lt	Stapes Mobilization
15	M	36	Rt	Stapes Mobilization
16	M	32	Rt	Stapes Mobilization
17	M	26	Lt	Stapes Mobilization
18	M	22	Rt	Fenestration
19	M	21	Rt	Stapes Mobilization

Group Observations Because the aural-harmonic test was administered using fundamental tones of 1000 and 2000 cps only, Table IV presents the gross data for all measures taken on each of the subjects at these two frequencies only The first group of seven cases are those on which the fenestration operation was performed, and the remaining cases submitted to the stapes-mobilization procedure The means for the two separate groups, as well as the entire sample, are provided in the Table The data obtained by air- and bone-conduction studies were eliminated for those ears in which aural-harmonic data were incomplete Arithmetical calculations were carried to the nearest whole number

Case 4, which will be examined in detail later, showed a marked decrease in air and bone sensitivity and in the harmonic threshold following surgery Because there was reason to believe that the negative result was due to the operative procedure rather than to poor cochlear reserve pre-operatively, the data collected on this case were not used in calculating means

Except for Case 4, every patient showed an improvement in air-conduction sensitivity at both frequencies in question, ranging from 5 to 40 db (mean of 22 db) at 1000 cps and from 10 to 30 db (mean of 19 db) at 2000 cps

Again excluding Case 4, bone-conduction sensitivity improved from 5 to 30 db in 15 ears in the 1000 cps column, and from 5 to 20 db in 12 ears in the 2000 cps column The remaining showed no improvement in bone conduction, which was consistent at both frequencies for Case 10 and for Case 14 in the right ear The mean improvement in bone conduction for all of the ears tested at 1000 cps was 10 db and 9 db for those tested at 2000 cps

All of the cases completely tested in this study had a pre-operative linear range of hearing of 35 db or greater, meeting the requirements of normal cochlear reserve

A discrete aural-harmonic threshold was not obtained in Case 17 at 1000 cps , and in Cases 11, 12 and 15 at 2000 cps This was due to the intensity restrictions of the fundamental tone in the clinical equipment used The maximum intensity available at either frequency was 100 db *i e* audiometric zero In all of the cases in which pre-operative thresholds

TABLE IV

THRESHOLD DATA OBTAINED IN EACH EAR COMPLETELY TESTED—IN DECIBELS

		1000 cps									2000 cps								
		Air Conduction			Bone Conduction			Harmonic Thresh			Air Conduction			Bone Conduction			Harmonic Thresh		
	No	Pre-op	Post op	Chg	Pre-op	Post-op	Chg	Pre op	Post op	Chg	Pre-op	Post-op	Chg	Pre-op	Post-op	Chg	Pre-op	Post-op	Chg
FENESTRATION	1	50	25	25	20	15	5	40	50	10	50	25	25	10	5	5	15	50	5
	2	50	10	40	10	–10	20	50	55	5	50	25	25	15	–5	20	10	45	5
	3	50	15	5	15	10	5	15	10	–5	15	35	10	20	20	0	35	35	0
	6	40	20	20	15	–5	20	45	15	0	25	5	20	5	–5	10	50	15	–5
	7	50	25	25	10	–5	15	35	40	5	30	10	20	5	–10	15	65	60	–5
	11	60	30	30	25	–5	30	40	50	10									
	18	35	5	30	15	0	15	10	10	0	35	10	25	5	–10	15	55	55	0
	Mean	48	23	25	16	0	16	43	46	3	39	18	21	10	–1	11	18	18	0
STAPES MOBILIZATION	4*	30	50	–20	5	15	–10	10	35	–5	30	55	–25	5	20	–15	10	30	–10
	5	25	15	10	10	0	10	50	50	0	35	25	10	30	15	15	50	50	0
	8	45	30	15	20	0	20	35	40	5	45	30	15	20	0	20	15	50	5
	9	55	35	20	15	10	5	35	30	–5	15	25	20	15	0	15	55	50	–5
	10	30	20	10	20	20	0	40	40	0	20	10	10	10	10	0	50	55	5
	12	40	10	30	–5	–10	5	45	15	0									
	13	10	15	25	5	5	0	55	65	10	35	20	15	5	0	5	60	65	5
	11	40	10	30	5	5	0	50	50	0	25	15	10	–5	–5	0	65	55	–10
		35	0	35	10	0	10	55	55	0	25	0	25	–5	–5	0	55	55	0
	15	30	15	15	15	5	10	60	65	5									
	16	45	25	20	15	5	10	10	45	5	10	25	15	10	0	10	15	15	0
	17										45	15	30	15	10	5	45	15	0
	19	25	5	20	10	5	5	55	55	0	30	0	30	15	0	15	55	55	0
	Mean*	37	16	21	11	4	7	17	19	2	35	17	18	11	3	8	53	53	0
	Total M*	11	19	22	13	3	10	45	18	3	36	17	19	11	2	9	51	51	0

*Results obtained in Case 4 were not included in the calculation of the sub-group or total mean data See Results for the reason for this omission could not be obtained, this intensity was not sufficiently high to produce aural harmonics, however, in all of these ears, no evidence of amplitude distortion was detected at a sensation level of less than 50 db, thus connoting normal cochlear reserve under the terms of delineation accepted for this study

The harmonic threshold at 1000 cps changed post-operatively from a linear range that was 5 db less than the pre-operative level to one that was 10 db more than this intensity, at 2000 cps the range was from 10 db less to 5 db more Thus there was never more than a 10 db change from the pre-operative to the post-operative linear range of hearing for any patient tested Considering that there is at least a 5 db error of measurement accepted in almost all clinical audiometry involving intensity increments of 5 db, this seems quite stable The mean change was 3 db at 1000 cps, and 0 db at 2000 cps In no case in which there was post-operative improvement in air conduction did the harmonic threshold decrease or increase post-operatively beyond one standard deviation from the normal mean as given in Table II

Because of the comparative size of the samples, no attempt was made to compare the results statistically in terms of the two types of operations employed, however, it is interesting to note that the greatest mean improvement in air and bone conduction at 1000 cps occurred in the "fenestrated" group (25 and 16 db respectively, as compared with 21 and 7 db for the "mobilized" group) At 2000 cps there was also slightly more improvement in air conduction in the "fenestrated" group (21 db compared to 18 db) and in bone conduction (11 db and 8 db respectively)

Fig 2 is a composite audiogram of the mean pre- and post-operative air and bone-conduction thresholds for the entire group The mean harmonic thresholds are also provided It is immediately apparent upon examining the changes occurring in hearing sensitivity for the three tests employed that there is a definite mean improvement in air and bone sensitivity for pure tones but, comparatively, an extremely small change, if any, in the linear range of hearing for the entire sample

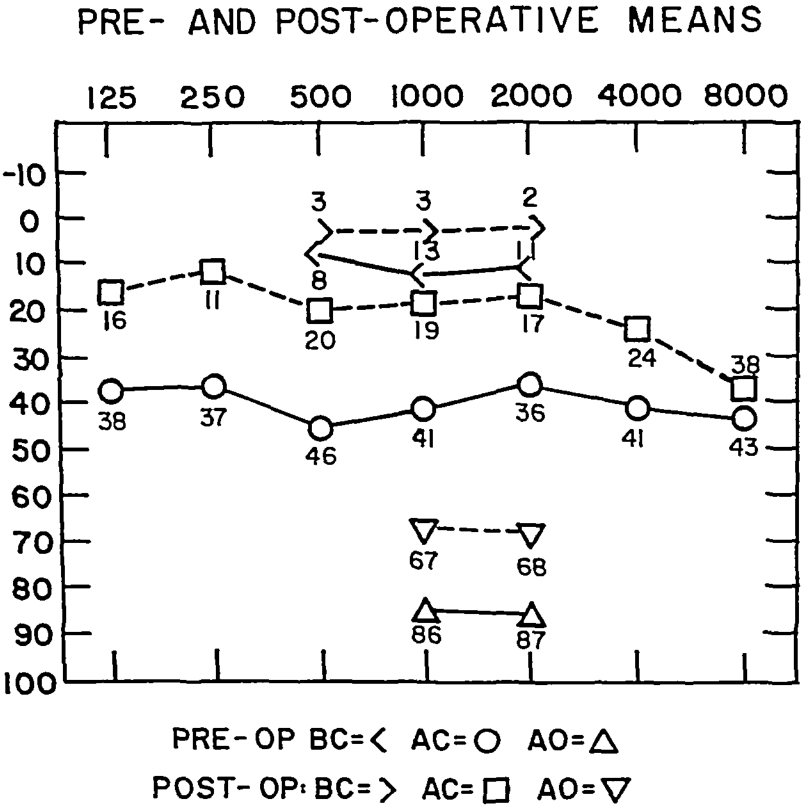
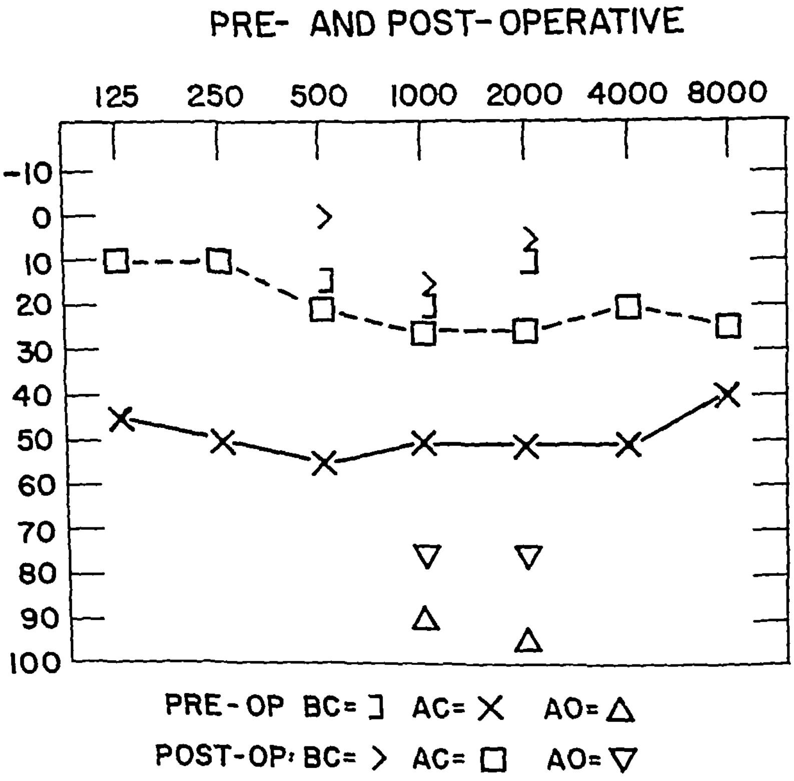


Fig 2 Graphic representation of the mean pre- and postoperative thresholds for air conduction bone conduction and aural-harmonics found in the ears in which all three tests were conducted in this study The numerical mean thresholds are recorded AO refers to the aural-harmonic (aural-overload) threshold

Illustrative Cases In order to demonstrate the particular types of problems and results that arise in individual cases and to illustrate the differences that can occur between patients, the results obtained in the first five ears tested are presented and discussed The pre- and post-operative air, bone and harmonic thresholds *re* audiometric zero are presented in the figure referred to for each case

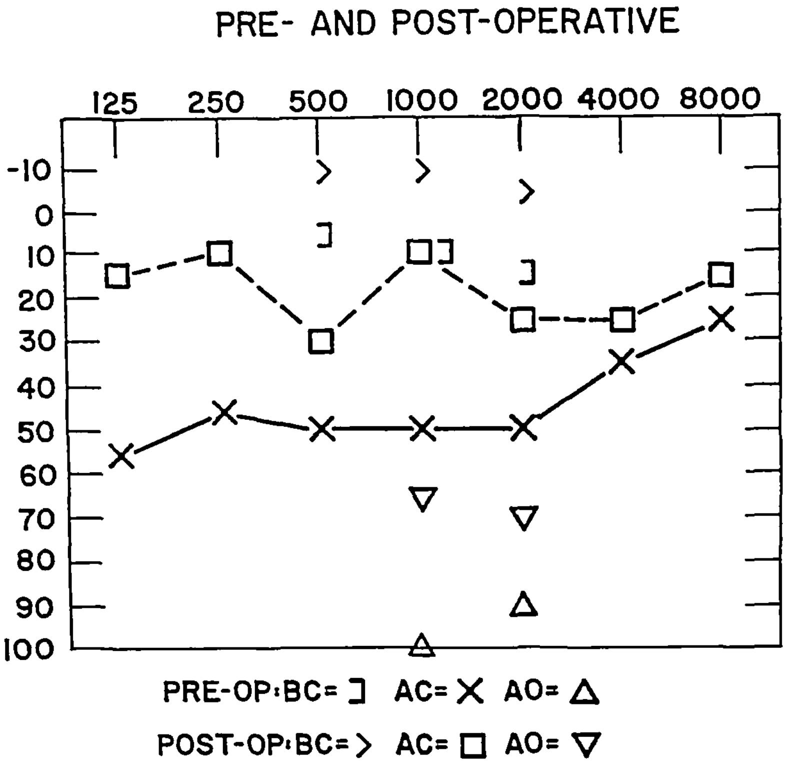
Case No 1 (see Fig 3) Female age 28 years Left fenestration The pre-operative air and bone sensitivity in this case presents a good prognosis for operative intervention There is an air bone gap of 30 db at 1000 cps and a gap of 40 db at 2000 cps A normal linear range from air-conduction threshold to the aural harmonic threshold confirms the presence of good cochlear reserve



AUDIOMETRIC DATA

FREQUENCY: 1000				2000		
TEST	PRE-OP	POST-	CHNG	PRE-OP	POST-	CHNG
A C	50	25	+25	50	25	+25
B C	20	15	+ 5	10	5	+5
A O	40	50	+10	45	50	+ 5

Fig 3 Results obtained in Case No 1



AUDIOMETRIC DATA

FREQUENCY=	1000			2000		
TEST	PRE-OP	POST-	CHNG	PRE-OP	POST-	CHNG
A.C	50	10	+40	50	25	+25
B C	10	-10	+20	15	-5	+20
A.O	50	55	+5	40	45	+5

Fig 4 Results obtained in Case No 2

Post operatively the good prognosis for air conduction improvement is borne out by a significant rise in air conduction sensitivity, providing socially adequate hearing in the operated ear, however the expected improvement in bone conduction is not large only 5 db at the two frequencies of interest Harmonic thresholds are improved slightly, and are still well within one standard deviation of the normal mean

The important fact illustrated here is that although in the large number of cases there is an expected improvement in bone sensitivity post-operatively it cannot always be relied upon in individual cases In this patient there was enough of an air bone gap to insure at least fair cochlear reserve and the results of harmonic threshold studies provided secure reinforcement of this conclusion

Case No 2 (see Fig 4) Male age 29 years Left fenestration The results obtained in this case illustrate quite remarkably the comparatively stable characteristic of the linear range of hearing after successful surgery as opposed to a large change in bone-conduction sensitivity, and shows the changing vs stable' quality of the two tests that is generally found It is evident that the pre-operative bone-conduction measurements were actually inaccurate to the extent of 20 db at 1000 and 2000 cps which is even a greater degree of inadequacy than could be accounted for by the application of the Carhart "notch" formula Again the possibility of good cochlear reserve was confirmed by a normal linear range of hearing

Case No 3 (see Fig 5) Male age 52 years Right fenestration At first examination the data collected on this patient were almost identical before and after surgery at least at the middle frequencies of interest in this study On the basis of the pre-operative air and bone threshold alone the prognosis would have been good, especially after applying the "notch' formula for bone-threshold corrections Nothing abnormal was noted in the pre-operative aural harmonic threshold at 1000 cps however, the linear range at 2000 cps was comparatively restricted and a guarded prognosis based upon selectively questionable cochlear reserve at 2000 cps was made

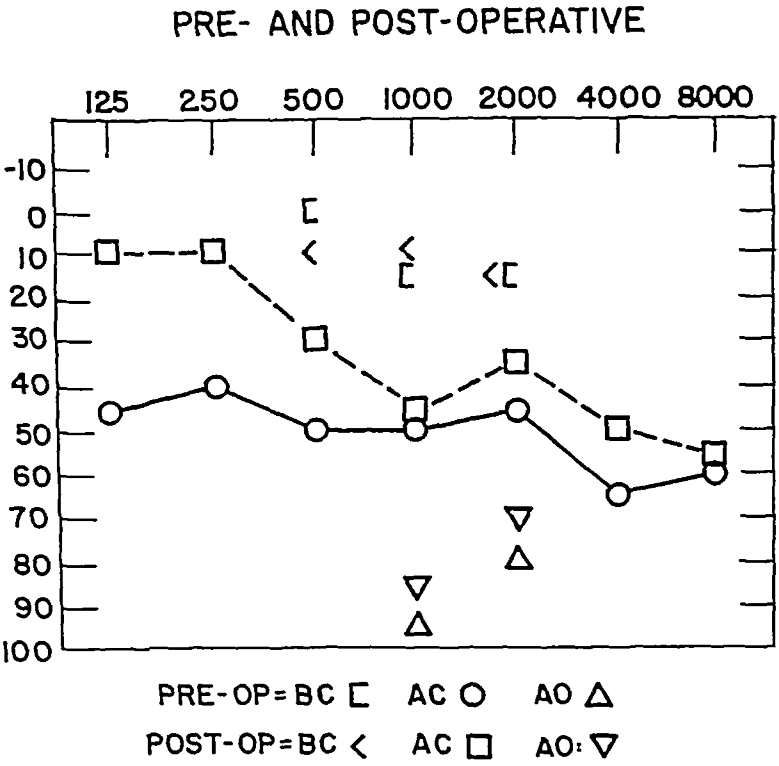
Because of the normal linear range at 1000 cps surgery was carried out Post operatively there was significant improvement in air conduction sensitivity for the lower frequencies but very little at 1000 cps and 2000 cps Bone conduction improved only 5 db at 1000 cps and remained stable at 2000 cps The harmonic thresholds remained essentially the same

In retrospect it is assumed that the slightly restricted and unchanged linear range at 2000 cps indicated localized cochlear pathology at least involving the higher frequencies This seems to be confirmed by the unchanged loss in bone sensitivity at 2000 cps and the lack of improvement in air conduction post operatively which is associated only with the higher frequencies

Case No 4 (see Fig 6) Female age 21 years Left stapes mobilization Although the outcome of surgery in this case was unfortunate it is chosen to illustrate the use of the aural harmonic test in determining the locus of damage in an unsuccessful procedure

Pre-operatively the test results were consistent with a diagnosis of good cochlear reserve and the prognosis for improvement was favorable

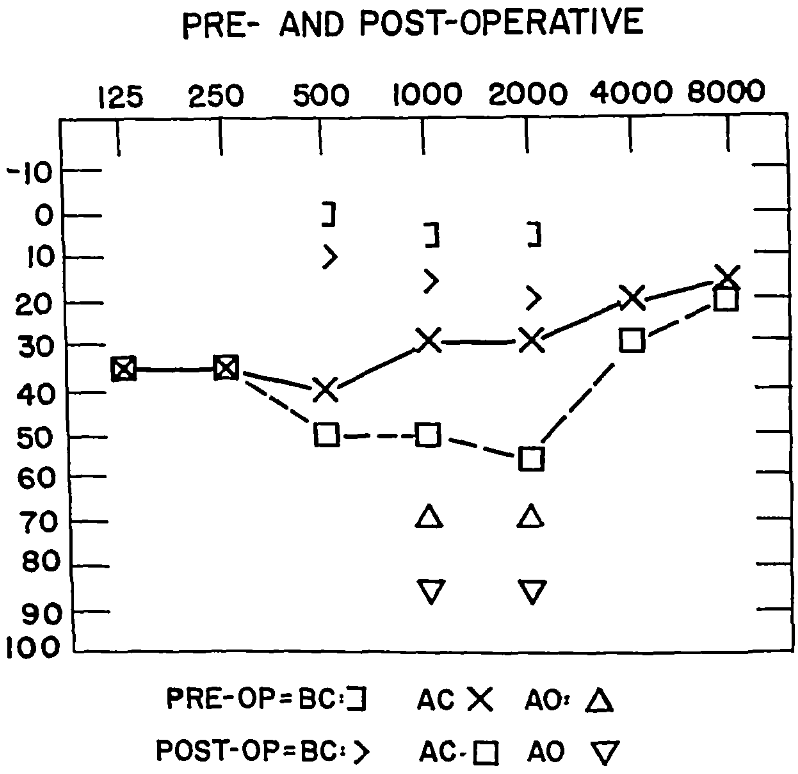
Post-operatively we find not only a decrease in air and bone sensitivity but, more significantly a lowering of the linear range of hearing by 15 db at 1000 cps and 10 db at 2000 cps These post-operative measurements were made four months after surgery and indicate a stable condition These findings were interpreted as showing the presence of mild



AUDIOMETRIC DATA

FREQUENCY	1000			2000		
TEST	PRE-OP	POST-	CHNG	PRE-OP	POST-	CHNG
AC	50	45	+5	45	35	+10
BC	15	10	+5	20	20	0
AO	45	40	-5	35	35	0

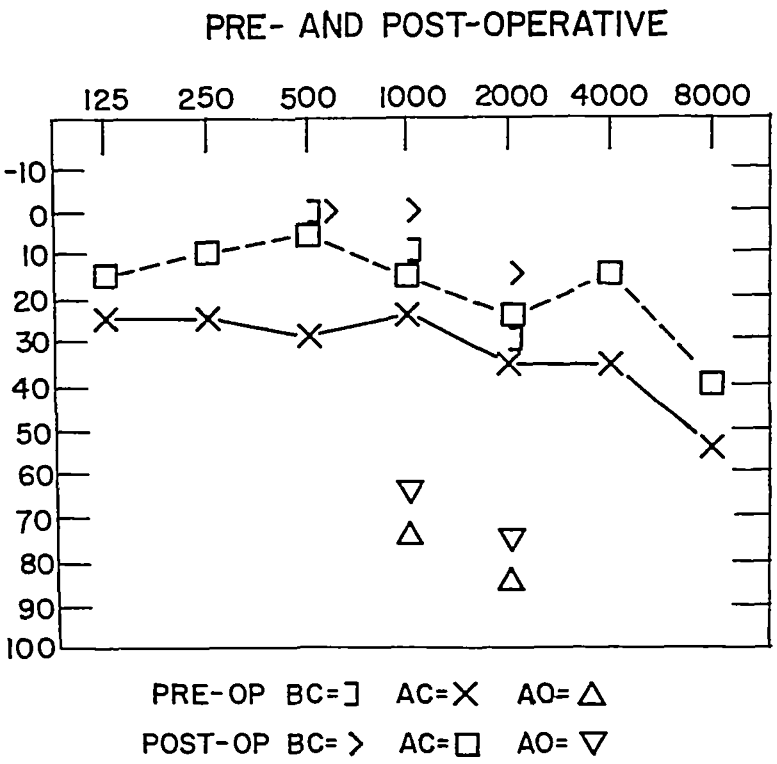
Fig 5 Results obtained in Case No 3



AUDIOMETRIC DATA

FREQUENCY:	1000			2000		
TEST	PRE-OP	POST-	CHNG	PRE-OP	POST-	CHNG
A C	30	50	-20	30	55	-25
B C	5	15	-10	5	20	-15
A O	40	35	-5	40	30	-10

Fig 6 Results obtained in Case No 4



AUDIOMETRIC DATA

FREQUENCY:	1000			2000		
TEST	PRE-OP	POST-	CHNG	PRE-OP	POST-	CHNG
A.C	25	15	+10	35	25	+10
B C	10	0	+10	30	15	+15
A O	50	50	0	50	50	0

Fig 7 Results obtained in Case No 5

cochlear involvement of a permanent nature most probably due to operative intervention however, the conductive component is still quite large, and the patient may still profit by fenestration surgery

Case No 5 (see Fig 7) Female, age 41 Left stapes mobilization The pre-operative air conduction threshold curve shows a moderate loss in the ear in question but of a sufficient degree to lead the patient to seek medical treatment The bone-conduction threshold is within normal limits for 500 and 1000 cps, but bone sensitivity is only 5 db better than the air conduction threshold at 2000 cps On the basis of the audiogram alone an interpretation of poor cochlear reserve involving the high frequencies could easily have been made, however linearity measures at both 1000 and 2000 cps were found to be normal and mobilization of the stapes was carried out

Post operatively, the air-conduction curve is shifted upwards to fall within the normal range for most frequencies Bone conduction is improved by 10 db at 1000 cps and 15 db at 2000 cps The level of the harmonic threshold remains unchanged

This case illustrates at 2000 cps how fallacious it can be to depend entirely on the 'air bone gap" for a discriminating evaluation of cochlear reserve The pre-operative status of the cochlea for stimulation by a tone of 2000 cps was inaccurately shown by bone measurement, as attested by a normal and unchanging linear range of hearing at this frequency, as well as a significant improvement in bone sensitivity at 2000 cps after surgically reducing the degree of stapes ankylosis previously present

DISCUSSION

The general observation that bone-conduction sensitivity is improved after fenestration or stapes-mobilization surgery in the majority of cases of otosclerosis is confirmed in this study It is safe to assume, on the basis of the evidence accumulated by the investigators dealing with this problem, that we cannot place complete reliance on the pre-operative bone-conduction threshold as an *accurate* indicator of true cochlear reserve in all of these patients We also cannot expect a post-operative improvement in bone sensitivity of a certain pre-determined amount in the majority of individual cases It seems reasonable to assume that the otosclerotic lesion, involving a reduction in movement of the footplate of the stapes, has a direct influence on the physiology of bone conduction, and that the removal of this condition, either by restoring stapes mobility or creating a labyrinthine fenestra, restores bone-conduction sensitivity to the level expected in the light of the existing cochlear function

In attempting to explain the reasons for the general improvement of bone conduction after surgical intervention, let us review briefly the theory of cochlear stimulation by osseous conduction and discuss the probable influence of otosclerotic pathology and surgery on the physiology of bone conduction

The pathways of sound to the cochlea by bone conduction have been well defined by Guild,[27] and are familiar to all students of the hearing process The osseous pathway, from the vibrator to the otic capsule directly through the bones of the skull, has been generally accepted as of much greater importance than the so-called osseo-tympanic route from the vibrator to the middle-ear cavity and thence to the round-window membrane

The two modes of cochlear stimulation that have received maximum attention in the past are the translatory, or inertia, form of bone conduction, and the compressional mode In translatory bone conduction, the contents of the cochlear capsule do not move in the same time relation with the bodily movement of the capsule itself Because of the elastic qualities of the oval and round windows, the inertia of the cochlear fluids allows for a time lag in movement Inertia opposing the vibratory force is also provided by the ossicular chain When the labyrinthine capsule is placed into movement, the footplate of the stapes lags behind, due to the restraint on the stapes provided by the inertia of the ossicular chain Thus, under these two conditions, the cochlear fluids are displaced relative to the capsular walls, providing concomitant displacement of the basilar membrane and resultant stimulation of the hair cells

The compressional mode of bone conduction calls for periodic volume displacements of the cochlear fluids in direct relation to, and synchronous with, the periodic condensations and rarefactions of the stimulus sound The theory implies that the entire labyrinthine capsule expands and contracts in response to stimulation, and that every portion of the capsular wall is vibrated with approximately the same force A compression of the capsule would bulge out the round window due to fluid displacement, and a rarefaction would have the opposite influence on the membrane In either case, resultant movements of the basilar membrane would produce neural stimulation

The studies of Bárány,[29] Bekésy[30] and Smith[17] all amplify the importance of the translational mode of stimulation The compressional form is considered to be less significant and not affected to a great degree by stapes fixation [17] Accepting this conclusion, we are led to the belief that in order to achieve adequate stimulation of the organ of Corti by bone-conducted sound, it is necessary to have at least two elastic membranes in the walls of the labyrinthine capsule in order to provide adequate mobility of the labyrinthine fluids with concomitant activation of neural impulses by hair-cell stimulation When the impedance of the ossicular chain is increased by stapedial fixation due to otosclerosis, the normal translational mode of cochlear stimulation by bone-conduction is altered and, in the majority of cases, bone sensitivity is reduced When normal mobility of the fluids is restored, either by restoration of stapedial vibration in the oval window or by the surgical provision of a new window in the horizontal semi-circular canal, an improvement in bone-conduction sensitivity is usually seen

That certain changes in the status of the middle ear can influence the accuracy of bone sensitivity has also been borne out by studies involving conditions other than otosclerosis Bárány[29] studied the effect of reduced middle-ear air pressure on bone-conduction sensitivity at 435 cps , and found that in the normal human ears examined, bone sensitivity was reduced approximately 10 db under this condition It could be hypothesized that the reduced air pressure in the tympanic cavity lowered the normal quality of mobility of the round-window membrane Recently, Palva and Ojala,[31] after testing a series of 42 ears with catarrhal or purulent otitis media, in some of which bone conduction was improved after myringotomy, aspiration and subsequent healing, concluded that in certain cases of conductive-type hearing loss, the initially lowered bone-conduction threshold "does not necessarily indicate a perceptive involvement, but may be due to impaired mobility of the oval and round window "

Technically, there should be little difference between the stapes mobilization or fenestration procedures in the inherent quantitative restoration of bone sensitivity In the former technique, the original anatomic and physiological condition of the middle-ear structures are functionally restored In the latter operation, although the transformer action of the ossicular chain is no longer present, there still is a sufficient difference in the phase relationships of the round window and the fenestra to insure adequate fluid mobility, providing the tympanic flap adequately isolates the round-window membrane

As mentioned in the results of this study, it was found that there was a comparatively greater improvement in the mean air and bone thresholds in those ears that had undergone fenestration surgery Except for the mean bone-conduction threshold at 2000 cps , the original extent of hearing loss was greater, on the average, in the "fenestrated" group, and yet at both frequencies post-operatively, there was a greater improvement in mean threshold in the latter group These observations, though broad and inconclusive, lead one to speculate whether the formation of a new window, with relatively small inherent impedance characteristics as compared to the status of the normal oval window, produces better opportunities for more normal fluid mobility The answer to this problem must, of course, await further exploration

One important advantage of the aural-harmonic test, both physiologically and clinically, is its relatively stable characteristic under conditions of middle-ear pathology or surgical intervention Although normal bone-conduction sensitivity depends to some extent on the relative normality of the middle ear, the process of recording amplitude distortion by the exploring-tone technique is not affected by any malfunction of the middle-ear mechanism Normal measurements of linearity may be recorded even when the ossicular chain, down to the footplate of the stapes, is removed[32] Thus, the critical factors of fluid mobility and general loss in air-conduction sensitivity affecting bone conduction have relatively no effect on distortion measurements using the exploring-tone technique The fact that a quantitative threshold may be obtained by the aural-harmonic procedure connotes the possibility that a quantitative evaluation of cochlear function may be determined It is apparent that such a measure would be of great value in determining the efficacy of surgery, and it may have some importance in discerning the relative advantages of one operative technique over another in an individual case, however, until a much greater pathological sample is studied, we must be satisfied with the present use of the procedure in diagnostically delineating cochlear involvement

In studying and endeavoring to interpret the means presented in Table IV, it must be emphasized that in the realm of operative prognosis in the patient with otosclerotic deafness we are concerned with discrete and individual anatomic, physiological and pathological problems that may vary remarkably with each patient encountered Although the application of certain group measurements of auditory function to an individual case may be helpful in pointing out a general trend, they cannot be relied upon implicitly to give an accurate picture of future measurements This is especially so after operative intervention with all of the concomitant parameters of technique involved, and unknown resultant changes in the physiological conduction of sound by the middle-ear mechanism in the case of the stapes-mobilization procedure For example, in only one ear in this study (Case 5) were pre-operative corrections of the bone-conduction curve, as determined by the "otosclerotic notch" principle, confirmed post-operatively The primary importance of this principle is that it has brought to the attention of otologists the fact that a pre-operative bone-conduction audiogram obtained in an ear with otosclerosis is a relatively inaccurate indication of the actual capacity of the organ of Corti to be stimulated by sound conducted through the osseous pathway

In being critical of group results obtained by bone-conduction testing, it would also seem consistent to be equally critical of group means obtained by the aural-harmonic test, however, it must be emphasized that a different physiological principle is involved in measuring cochlear distortion We need not be concerned with the possible changes in the anatomical or physiological condition of the middle ear since any changes, even of a gross nature, have an insignificant effect on the measurement of cochlear distortion in terms of sensation level The studies of Wever, Bray, and Lawrence on animals,[17 32 33 34] and the results obtained in human ears such as tested in this study, substantiate this conclusion

One main observation is emphasized In the patients tested in this study, it was found that there is less change in the mean harmonic threshold post-operatively than in the mean bone-conduction threshold, and that in terms of accuracy and stability it is felt that more reliance can be placed on the aural-harmonic test as a direct measure of cochlear function This observation seems of value in obtaining more consistent pre-operative measures of cochlear function in cases of clinical otosclerosis, however, of far greater importance, we feel, are the observations and interpretations made in the individual case with respect to variations and consistencies in the two techniques

In conclusion, it seems somewhat fallacious in developing a prognosis for either fenestration or mobilization surgery to be satisfied with the principle of "closing the air-bone gap" as determined by pre-operative examination It is certainly true that successful operative intervention will, in most cases, bring air-conduction sensitivity close to the pre-operative bone threshold, however, it is our belief that the otologic surgeon still has the responsibility of determining the condition of cochlear function as accurately as possible, before attempting to predict the effects of surgery in the individual case The comparison of air- and bone-conduction sensitivity alone is not adequate in most cases Qualitative judgments can be made with other tests, such as loudness-balance recruitment techniques, the discrimination score for speech, etc Our experience with the aural-harmonic test as one of a battery of such procedures has been very helpful The use of this technique as an actual quantitative measure of cochlear function has interesting potentialities, and the accumulation of data in a significantly large sample of otosclerotic ears is now being carried out in an attempt to determine the merit of this possibility

SUMMARY

Pertinent literature is reviewed, citing evidence for the post-operative improvement of bone-conduction sensitivity in the ear with a hearing loss due to clinical otosclerosis It is emphasized that in most cases the measurement of bone-conduction thresholds in the ear with otosclerotic pathology may give an inaccurate picture of the true capability of the organ of Corti to respond to osseous stimulation

The theory behind the aural-harmonic (aural-overload) test as a measure of cochlear function is briefly reviewed, and previous studies on human ears are discussed In order to compare the relative stability of the two techniques (bone-conduction and harmonic measurements) in the evaluation of cochlear reserve, air-conduction, bone-conduction and aural-harmonic thresholds were obtained before and after either stapes mobilization or fenestration surgery in 19 patients with clinical otosclerosis A total of 20 ears was examined

It was found that at 1000 cps there was a mean improvement of 22 db for air conduction, 10 db by bone conduction, and a mean change in the linear range of hearing of only 3 db In the ears tested completely at 2000 cps, a mean improvement of 19 db in the air-conduction threshold, a change of 9 db in bone conduction, and no mean change in the harmonic threshold was found, thus, in this sample, the aural-harmonic test was found to be a more stable measure than the bone-conduction threshold Five illustrative cases are presented and discussed

The influences of stapes ankylosis and surgical intervention on the physiology of bone conduction are discussed It is concluded that more reliance must be placed on audiometric techniques that are not influenced by anatomic and physiological changes in the middle ear in attempting to judge the status of the organ of Corti adequately The aural-harmonic test, as one of a battery of such techniques, is proposed as an adjunct to a complete diagnostic evaluation of the patient with clinical otosclerosis

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Department of Otolaryngology, University Hospital

THE CONTROL OF ITCHING OF THE EXTERNAL EAR WITH SANDOSTENE®

WALLACE RUBIN, M D ,
and
JACK R ANDERSON, M D ,
New Orleans, La

A number of investigators have reported the effective use of Sandostene® in relieving pruritis associated with a variety of allergic dermatologic conditions This is a first report of the use of this preparation exclusively for the relief of pruritis associated with external ear conditions We have evaluated Sandostene® in 147 cases of itching associated with pathology of the external ear The control of itching has been dramatic, and the incidence of side effects has been minimal

Sandostene® chemically is 1-Methyl-4-amino-N^1-phenyl-N^1-(2^1-thenyl) piperidine tartrate The drug is commercially available as an enteric coated tablet, each tablet containing 25 milligrams of the active substance Pharmacologically, Sandostene® has been shown to exhibit a variety of effects which would influence allergic processes Its three physiologic actions, antipermeability, anticholonergic action and histamine antagonism make it ideally suited for the treatment of pruritis, as well as for controlling allergic responses

The control of itching in the external ear is a most important therapeutic problem The patient traumatizes the skin of his ear canal in an attempt to relieve the symptoms of itching, and in this way opens the pathway for infection Scratching is an attempt to replace the burning, itching feeling with a less unpleasant sharper sticking but more painful sensation The painful sticking sensation replaces the burning itching sensation even though itching fibers are still being stimulated As soon as we stop scratching, the painful sensations of short duration cease, and the itching sensation again becomes pronounced We then try to replace it with

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sticking pain by scratching, and the more we scratch the more after discharge of unpleasant itch occurs The scratching traumatizes the ear canal, and in this way secondary infection can begin

MATERIAL AND METHOD

This study was based on observations made in 147 patients seen in private practice over a period of approximately one year All complained of various degrees of itching associated with pathology of the external ear In some cases the pathology was primary in the external ear, and in a number of cases the pathology was secondary to middle ear infections

This study was designed to evaluate the symptomatic relief of itching and to determine whether the relief of itching influenced the length of time necessary to control the pathologic condition We were interested in determining the most effective dosage of Sandostene® for controlling itching, and we were further interested in determining whether we could prevent external ear infections which were due to scratching the skin of the ear canal in an attempt to relieve itching

DOSAGE

Sandostene® in 25 mm tablets, coated and uncoated, were available at various times during our study Our dosage routine varied and was influenced by the response of the patient In acute conditions where there was infection and marked itching, we started the patient on 50 mgm Sandostene®, four times a day When there was no relief with the first 24 hours, we instructed the patient to double the dosage so that the total dosage would reach 400 mgm per day In instances where there were side effects of drowsiness or nausea we instructed the patient to drop the dosage to 25 mgm four times a day

After a 72-hour-dosage schedule such as outlined above, the patients were instructed to cut the dosage of Sandostene® to either 25 or 50 mgm as necessary for itching In a small number of cases where the medication was used for children or in adults who could not easily swallow tablets, Sandostene®

syrup was used There seemed to be no difference in the therapeutic effectiveness of the medication when used in the form of syrup

Patients reported relief from itching in 20 to 30 minutes when Sandostene® was used The duration of effect was very difficult to evaluate, as the medication was taken routinely at four hour intervals in acute cases When the patients were on the PRN dosage schedule, they experienced relief from itching for as long as 24 to 48 hours Obviously, this did not indicate a prolonged Sandostene® effect, but rather that itching did not recur

TABLE I

Diagnosis	No of Patients	Dosage 200mg per day	Dosage Other	Other Treatment	Relief of Itching Within 24 Hours Comp	Relief of Itching Within 24 Hours Part	Relief of Itching Within 24 Hours None	Side Effects Dry mouth	Side Effects Nausea
Diffuse External Otitis	69	50	19	51	60	6	3	3	4
Eczematoid Ext Otitis	33	26	7	24	27	3	3	2	4
Secondary External Otitis	9	8	1	9	2	4	3	1	0
Postoperative	6	5	1	6	0	3	3	1	0
Perforation	1	1	0	1	1	0	0	0	0
Chronic Otitis Media	2	2	0	2	1	1	0	0	0
Otomycosis	6	4	2	6	0	0	0	0	0
External Canal Pruritis (No Specific Etiology)	6	6	0	0	4	2	0	0	0
Circumscribed External Otitis	24	19	5	15	9	9	6	1	0

RESULTS

The summary of findings are indicated in Table I The summary indicates that the majority of cases treated were either diffuse external otitis or eczematoid external otitis There was relief of itching in approximately 90 per cent of these cases within 48 hours The majority of these cases were using other local and systemic medications to control the diffuse infection In our experience only 30 per cent of patients are relieved of itching with the usual general or local therapeutic agents

In the classifications of otomycosis and external otitis secondary to middle ear pathology the relief of pruritis was prompt and complete, regardless of the causative organism

Of special interest to us were the cases in the category of external canal pruritis with no specific etiology Here again there was complete relief of itching, this therapeutic response was not reproducible with any other medication

The category in which the poorest results were obtained was in the circumscribed external otitis Relief of itching was observed in only about 50 per cent of the cases, and this closely approximated the results obtained with other medications

SAFETY

The incidence of side effects was approximately 10 per cent Nausea and marked dryness of the mouth were experienced, but neither were of particular consequence as they were relieved by cessation of the use of the medication In all but two cases the patients were able to continue the use of the drug, as the side effects were so minimal in nature In only two cases did the patients volunteer the symptom of nausea or dryness of the mouth In the other 13 cases we had to elicit the symptom by direct questioning of the patients

CONCLUSION

In our series of 147 cases external canal pathology we have found that Sandostene® is an excellent therapeutic tool for the subjective relief of itching It provided relief of itching in 90 per cent of the cases studied and is, therefore, an excellent adjunct medication in the treatment of external otitis It is our belief that one of the primary factors in the pathophysiology of external canal infections, such as experienced in more humid climates, and infections associated with swimming, is that the patient responds to the itching of the ear canal by scratching The trauma inflicted opens pathways of infection that were not present, and an ear canal infection ensues

We have found that the use of Sandostene® for symptomatic relief of itching is extremely effective in preventing ear infections Individuals who have considered themselves as having chronic ear infections have been amazed to find that their flareups were few and far between when Sandostene® was used for the symptomatic control of itching Preventing scratching and subsequent trauma of the skin of the ear canal maintains the pH of the skin of the ear canal and thus prevents the development of conditions conducive to infection

SUMMARY

1 90 per cent of the patients treated obtained relief of pruritis, within the first 24 hours of Sandostene®, therapy

2 We have found that 50 mgm of Sandostene®, four times daily, is the preferred dosage for the first 72 hours, after that time dosage is altered to either 25 or 50 mgm taken as necessary for itching

3 We have further found that children can tolerate similar dosages either in the compressed tablet form or in the form of Sandostene® syrup

4 Ten per cent of cases experienced side effects of either nausea or extremely dry mouth, but in all cases the side effects responded either to lowering the dosage or discontinuing the drug

We have found no essential relationship between the cause of the external auditory pruritis and the ability of Sandostene® to provide relief of itching We feel very strongly that Sandostene® is an excellent agent to be used for its antipruritic effect in external auditory canal pathology

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*Sandostene® supplied by Sandoz Pharmaceuticals Division of Sandoz Chemical Works Inc. Route 10 Hanover N J

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3 CLEIN NORMAN W A New Anti-Histamine for Treatment of Various Allergic Manifestations *Ann Allergy,* March-April 1955

4 LINDEMAYR W Experience with Sandostene Combined with Calcium-Sandoz (ASZ 16) in the Treatment of Allergic Skin Diseases *Internat Arch Allergy and Applied Immunol.,* 7 1, 1955

5 SENTURIA B H ET AL. Symposium Medical Management of Chron

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*Sandostene® supplied by Sandoz Pharmaceuticals Division of Sandoz Chemical Works Inc. Route 10 Hanover N J

ic Otic Skin Infections *Trans Amer Acad Ophthalmol and Otolaryngol*, Sept Oct., 1954

6 SENTURIA, B H, ET AL An Evaluation of Certain Therapeutic Adjuncts and Procedures in the Treatment of Acute Diffuse External Otitis THE LARYNGOSCOPE, Dec 1954

7 SENTURIA, BEN H. Diffuse External Otitis Pathogenesis and Treatment THE LARYNGOSCOPE, May, 1955

COURSE IN RECONSTRUCTIVE NASAL SURGERY

The Department of Otolaryngology, University of Cincinnati College of Medicine, announces a Course in Reconstructive Surgery of the Nasal Septum and External Pyramid The course will be under the direction of Dr Maurice H Cottle, Professor of Otolaryngology, Chicago Medical School, and a selected faculty, in association with the American Rhinologic Society, April 12 through April 19, 1958 Class membership limited Tuition $350 00 Please apply to Dr Henry M Goodyear, Professor of Otolaryngology, College of Medicine, Eden and Bethesda Avenues, Cincinnati 19, Ohio

THE 11TH CONGRESS OF THE INTERNATIONAL ASSOCIATION OF LOGOPEDICS AND PHONIATRICS

The 11th Congress of the International Association of Logopedics and Phoniatrics will take place in London, August 17-22, 1959 The following official reports will be presented The Inheritance of Voice and Speech Disorders, Prof R Luchsinger, M D , Zurich, Defects of Articulation, Muriel Morley, B Sc , F C S T , Newcastle, The Physiology and Pathology of the Soft Palate, Prof Lucio Croatto, M D , Padua The official languages of the Conference will be English, French, and German

Those working in the field of Speech and Voice Therapy and all who are interested in this specialty are invited to attend and to submit papers

If intending to be present, whether submitting a paper or not, please inform the Congress Secretary at the earliest possible date

Papers are invited on subjects relevant to the three main reports or any other aspect of speech and voice Only one contribution will be accepted from any one member of the Congress and this must not have been previously published The Committee reserves the right to select papers Papers should be restricted to 15 minutes in length, demonstrations to 10 minutes In special cases 20 minutes may be allowed for a paper of great importance but only if application is made at the time of submitting the title Should a group of four or more people wish to present a symposium or a prepared discussion on a theme, consideration will be given to allocating up to one hour for such a contribution

Titles must be received by September, 1958 Summaries must be received not later than November 15th, 1958

All communications are to be sent to Peggy Carter, L C S T , 46 Canonbury Square, London, N 1

SUBCOMMITTEE ON HEARING IN CHILDREN

The American Academy of Ophthalmology and Otolaryngology, through its Subcommittee on Hearing in Children of the Committee on Conservation of Hearing, has been conducting a long-term nationwide study of problems relating to the conservation of hearing in children The specific aims are to develop the most efficient case-finding methods and to use these methods in estimating the magnitude of the problem in the country, to study state laws and review current practices and facilities for rehabilitation of hearing impaired children, to help develop methods for medical and surgical rehabilitation standards, and ultimately to use the Subcommittee findings in assisting professional workers to improve and enhance programs in hearing loss

In the second year of operations, a full-time Executive Director has been engaged, and offices established at the Graduate School of Public Health, University of Pittsburgh An initial study is being conducted in Pittsburgh to identify early medical signs and symptoms which may indicate danger of hearing impairment, to measure the psychological, social and other effects of such impairment and to develop efficient and economical methods for the testing of hearing in children The Pittsburgh study is a cooperative effort among the following The Subcommittee on Hearing in Children, the Graduate School of Public Health and the School of Medicine of the University of Pittsburgh, the Pittsburgh Board of Public Education, and the Allegheny County Department of Health.

The members of the Subcommittee on Hearing in Children are Dr John E Bordley, Baltimore, Dr Victor Goodhill, Los Angeles, Dr Hollie E McHugh, Montreal, Dr S Richard Silverman, St Louis, and Dr Raymond E Jordan, (Chairman) Pittsburgh. An advisory committee of consultants from the University of Pittsburgh includes Dr Samuel M Wishik, Dr Leo G Doerfler, and Dr Isidore Altman. Grants from the United States Children's Bureau through the Pennsylvania Department of Health and from the National Institutes of Health are providing financial support

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PROCEEDINGS
OF THE
INTERNATIONAL CONFERENCE
ON AUDIOLOGY

May 13 through 16, 1957

St Louis, Missouri

FOREWORD

In connection with the official Midwest tours scheduled for the Sixth International Congress of Otolaryngology, held in Washington, May 5-10, 1957, one of the Organizing Committee, (S R Silverman) was asked by numerous individuals, both in the United States and abroad, to organize an International Conference on Audiology in St Louis immediately after the Congress The chief purpose of this Conference would be to create a situation where laboratory investigators could share their views and findings with an interested and sophisticated clinical audience The themes explored by the Conference were the Assessment of Auditory Function, the Physiology of Audition, and the Relation of Hearing Loss to Noise Exposure

The goals of the Conference are summarized in the following extract from the welcoming address of the Chairman to the members of the Conference

To Participants in the International Conference on Audiology—A Cordial Welcome to St Louis

From many lands a common interest in hearing and deafness brings us together It is true that our primary interests may vary We may be concerned with the structure of the auditory system or with its function, or with the diseases that afflict it, or with the impairment in social efficiency brought about by hearing loss Some of us work in the laboratory, others in the clinic and still others in the classroom, but the rapidity with which our knowledge, nurtured by many sources, is increasing, suggests clearly and emphatically that we create situations, such as this Conference, where we may share information that enriches our understanding and stimulates our activity If the Conference contributes in some small measure to the enthusiasm and the wisdom with which you pursue your tasks in the field of hearing and deafness, those responsible for its organization will have been richly rewarded

* * *

Of the actual scientific and professional membership of the Conference, fields of interest were represented as follows Audiology, including teachers of the deaf and speech pathologists, 42 per cent, Otolaryngology, 39 per cent, Psychology, Engineering and Physiology, 15 per cent, and Commercial, including makers of electroacoustic instruments, 4 per cent

The editors of the Proceedings of the International Conference on Audiology were S Richard Silverman, Chairman of the Conference, Ira J Hirsh, Program Chairman, and Shirley K Hirsh, Conference Secretary

The Conference acknowledges with appreciation its indebtedness to the National Science Foundation of the United States Government for providing the major portion of its expenses through a grant to the Central Institute for the Deaf

The Conference expresses its gratitude to the members of the staffs and friends of the Central Institute for the Deaf, and the Department of Otolaryngology of Washington University for assistance in arrangements, and to the School of Medicine of Washington University for provision of meeting rooms

PROGRAM OF TECHNICAL SESSIONS

Tuesday Morning, May 14

WELCOME

Presiding S Richard Silverman Director Central Institute for the Deaf, Chairman International Conference on Audiology

The Honorable Raymond R Tucker Mayor of the City of St. Louis

Ethan A H Shepley Chancellor Washington University

SESSION A—CONTRIBUTED PAPERS

Chairman Ira J Hirsh Head, Psychology Laboratory, Central Institute for the Deaf, St Louis Mo

1 **Some Similarities Between Hearing and Seeing**

S S Stevens Professor of Psychology, Director of Psycho Acoustic Laboratory, Harvard University, Cambridge, Mass 508

2 ***An Attempted Synthesis of Psycho Acoustic Test Data in the Audiological Clinic***

J Donald Harris Head, Sound Branch Medical Research Laboratory, U S Naval Submarine Base New London Conn 527

3 **Triplet Testing and Training—An Approach to Band Discrimination and its** ***Monaural or Binaural*** **Summation**

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4 **Relation of the Lombard Effect to Speech Production**

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5 **A Comparison of Picture Response and Hand Raising Techniques in Pure Tone Audiometry with Young Children**

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6 **Progress in the Comparison of Sleep EEG Audiometry with Standard Audiometry**

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William G Hardy Director Hearing and Speech Center The Johns Hopkins Hospital Baltimore Md

Helmer R Myklebust Professor of Audiology Northwestern University Evanston Ill

Louise Trunquet Chief Audiometric Department University of Lyons France

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Open House—Central Institute for the Deaf Clinics and Research Building

Demonstration of classroom procedures with deaf hard-of hearing and aphasic children and also of testing and teaching techniques for children and adults

Research laboratories and shops were open for inspection and demonstration

Exhibitions included Central Institute Library and the Goldstein Collection of hearing aids

A film by Georg von Békésy was shown at 8 30 and 9 30 P M

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PROGRAM OF TECHNICAL SESSIONS

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C A Amesur Member National Advisory Council for the Education of the Handicapped Bombay India and
C Satyanarayana Professor of E N T Diseases Stanley Medical College Madras India 675

NATIONAL ORGANIZING COMMITTEE

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William G Hardy Johns Hopkins Hospital

John Lindsay University of Chicago

Philip E Meltzer Tufts University Medical School

S S Stevens Harvard University

Program Chairman

Ira J Hirsh Central Institute for the Deaf and Washington University

Conference Secretary

Mrs Shirley K Hirsh

Thursday Afternoon, May 16

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JOHN LINDSAY University of Chicago

PHILIP E MELTZER Tufts University Medical School

S S STEVENS Harvard University

Program Chairman

IRA J HIRSH, Central Institute for the Deaf and Washington University

Conference Secretary

MRS SHIRLEY K HIRSH

TUESDAY AFTERNOON SESSION,

May 14, 1957

THE ASSESSMENT OF AUDITORY FUNCTION

I. HEARING IN CHILDREN—PANEL DISCUSSION

CHAIRMAN	S. Richard Silverman, Director, Central Institute for the Deaf, St. Louis, Mo.
PANEL	Robert Goldstein, Research Associate, Central Institute for the Deaf, St. Louis, Mo. William G. Hardy, Director, Hearing and Speech Center, Johns Hopkins Hospital, Baltimore, Md. Helmer R. Myklebust, Professor of Audiology, Northwestern University, Evanston, Ill. Louise Trenque, Chief, Audiometric Department, University of Lyons, France

DR. SILVERMAN: The essayists were asked three questions in preparation for this discussion. These questions are as follows:

One. What goals, particularly with reference to educational recommendations, can be set for the testing of the hearing of young children?

Two. What evidence is there that results of hearing tests on young children can yield information about the pathology of auditory and other disorders?

Three. What particular testing techniques have you found to be most successful in yielding answers to either or both of the first two questions?

One, then, is a matter of goals; two, is a matter of evidence; and three, what do you actually do when you assess the hearing of a young child?

Dr. Hardy, will you lead off?

DR. WILLIAM G. HARDY: Any one of these topics is worth an hour's discussion, so I am going to move through my material rather rapidly and hope that we may be able to pick up some of the more important indicators as the discussion proceeds

There are at least six objectives which we feel (I am talking as a representative of our departmental group) might well be kept in mind First, to ascertain the status and needs of the child regarding possible medical and surgical treatment This aspect of a problem is too often overlooked, and it must not be, particularly in dealing with younger children Incidentally, need we remind ourselves that we are not talking about a refined, preselected diagnostic group, all of whose problems are solely centered in hearing? The children we meet at the age of one, two, or three years, are referred because they do not talk, because they have not learned language, because they have not developed normally The reasons for these defects are manifold, involving much more than the possibility of impaired hearing

Second, to measure or estimate the child's potential for learning language and verbal communication Fundamental to this, perhaps, is the potential of the auditory mechanism, but by no manner of means should the inquiry exclude other sensory modes of learning

Third, to differentiate among several possible reasons for the lack of development of language and speech In terms of differential diagnosis, this may involve a tremendously complex inquiry We find that oftentimes this involves a closely integrated task among five or six of our major departments in the hospital

Fourth, to measure residual hearing as a basis for psychoacoustic development

Fifth, to try to learn the nature of the hearing impairment for what this information can contribute in terms of special needs in training Many of these objectives overlap, of course, and any effort to clarify reflects some of the comments in another paper given this morning our need to clarify our language in terms of what we mean by *hearing* Is hearing an "adequate response," or is it a "significant response" to a measured or variable set of stimuli, or is it simply "a response" Our references must be clarified, for in his experience with differential diagnosis one comes face to face very early with the realization that he inevitably is dealing with much more than the function of the auditory system The auditory system presents only one kind of information to the mind As one watches more and more of these tiny children who are apt to give sporadic, variable, inconsistent responses to sound, one is forced to wonder what this auditory experience is like to the child How can it be described in a single concept? Suppose that a given child has some disorder or lack of development at the level of difficulty in brief memory-span This might be directly, or only remotely, connected with an auditory deficit, yet what would the world of sound-stimulus, particularly speech-stimulus, be like to a little fellow who needs 75 milliseconds, instead of five milliseconds, in order to monitor his own vocal output? These are points of differentiation on which we have as yet barely begun to touch The modes of trying to apprehend, measure, and describe this sort of deficit are still in their infancy Related, without doubt, are variables in pitch-perception, perhaps at the cortical or immediately subcortical levels of the auditory mechanism

Sixth, to develop information relative to the nature of the hearing mind in terms of whatever effects of stimulus and inhibition can be observed in the responses of the child A child must go through a period of readiness to listen before he can progress very far in the development of language and speech This is, in part, a matter of the mind's meanings, of the conditioning of behavior to react or not to react to a particular sensory modality-like hearing It is probably at this stage of clinical judgment that one must differentiate between the fact of a child's response to sound, and a possible meaning of this experience to him Here we are at the level of cortical integration, and there simply is not time to discuss the many possible ramifications

I believe that all of these become extremely important objectives in an effort to refine hearing tests with reference to educational recommendations

Dr Hirsh, translating for Dr Louise Trenque *

DR IRA J HIRSH There are four major objectives one, is the child deaf? In the young child, in the majority of cases, the problem consists of establishing primarily whether or not deafness exists The fact that the child is helped most by the specialist from about 18 months on is because the language either does not appear or because the language is not developed normally Frequently the parents suspect the existence of deafness, but it is still necessary to confirm it

The second objective is to quantify the extent of the deafness Is deafness complete? Are there existing auditory residuals that might be used by the child in hearing speech efficiently? The value of these auditory residuals is most important if it appears that the child can hear speech partially, or possibly better with a hearing aid By using these residuals, for example, in perceiving some of the phonemes or the melody of the sentence, one can hope to rehabilitate the child completely Thanks to appropriate education this child can become capable of speaking with a voice that is comprehensible to all, capable of understanding what is said to him, and capable of acquiring even abstract thought at a level consistent with children of the same intellectual capacity and environment

Third, is deafness the only deficiency in the child? In our opinion it is of prognostic importance to ascertain whether the deafness is the only trouble, or whether there are others such as physical characteristics, deficiency in intelligence, difficulty in memorization and comprehension, superimposed upon the auditory deficit A large proportion of children in whom we have found audiometric curves of between 60 and 80 decibels, in whom, because of these auditory residuals, we have placed much hope, have disappointed us following the examinations In the course of their education, we were

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*Dr Louise Trenque was unable to attend the Conference because of illness She sent a manuscript however through one of the conferees which was received about an hour before the panel discussion was to begin Dr Hirsh's translation of her answers to the questions posed by the Chairman was therefore almost in the nature of a simultaneous translation There are many omissions and undoubtedly some errors but the Editors consider that at least her general point of view is fairly represented confronted with various difficulties, among the most severe of which have been dyslexia, dysgraphia, emotional instability, disorders in the development of learning, comprehension and intelligence, and those factors that interfere with the development of language beside those involved in the hearing

Finally, as the fourth objective, Dr Trenque lists the study of the origin of deafness This study has both therapeutic and prophylactic aims and can aid in our prognostic judgments therapy in cases of rhinogenic deafness, prophylaxis, for example, in the RH factor or syphilis, prognosis, as in cases where we observe obstetrical trauma

Dr Robert Goldstein Because our concern on this panel is primarily educational, we will consider the results of hearing tests as one basis for making educational recommendations My discussion today is restricted, first, to those auditory problems whose severity requires that education be handled, at least for a time, in special schools or special classes, two, to the very young children who have not yet had any individual or classroom instruction, from which we might ordinarily derive significant diagnostic clues, and third, to those children whose auditory disorder is not secondary to severe emotional disturbance or to mental deficiency

Our goals should depend primarily on what we know of the kinds of educational methods that have been used successfully on children with various auditory disorders My discussion is further restricted to what is known in general about the success of various approaches to oral education, acknowledging our desire to accord every child the opportunity for developing oral communication

Considering the present state of knowledge about the education of children with auditory disorders, I believe that we should find out from our hearing tests whether a child's auditory disorder results primarily from a serious reduction in auditory sensitivity or primarily from a defect in auditory perception and linguistic development

The education of hard-of-hearing children and deaf children, that is, children with varying losses of auditory sensitivity, although not uniform or simple, has been carried on with appreciable success, and has been described in some detail. By comparison, we know very little about the success in educating children whose disorder can be described as defective auditory perception, or as the inability to produce and/or to understand language. There are scattered reports of success with certain educational approaches, but there are no comprehensive reports in which an educational method has been described, the children taught by this method clearly defined and enumerated, and careful assessment of results presented. I feel competent, therefore, to refer only to our own experience for my contribution to the evaluation of this question.

We have classified a large number of our children as aphasic. We are aware of the controversies around this term, and for now, at least, we are not restricting ourselves to any particular definition of it. These children we call aphasic have as their main problem the inability to develop language, presumably because of some dysfunction of the central nervous system. This is not a homogeneous group, either from the standpoint of organic problems or from the standpoint of ability to use language; nevertheless, we use the same educational method with all of these children and achieve varying but considerable success with them. We make no attempt to develop a different procedure for each sub-classification of the aphasic group but modify certain aspects of our overall procedure when the situation calls for it.

If the findings on a particular child are inconsistent and do not clearly identify a child as deaf or aphasic, we generally recommend that this child be taught according to the system we use with aphasic children. We have found from experience that we do little educational harm to children who eventually prove to be simply deaf, by teaching them according to our system for aphasic children. On the other hand, we have seen much educational time lost on aphasic children who, because of uncertainty in diagnosis, were taught by methods conventionally used with deaf children.

On the basis, then, of our experience in educating children with auditory disorders, we try to answer this major question when we are examining a young child: is his inability to communicate primarily the result of a reduction in auditory sensitivity or is it primarily the result of a defect in auditory perception or in the ability to produce or to understand language?

DR SILVERMAN We turn now to our second question What evidence is there that results of hearing tests on young children can yield information about the pathology of auditory or other disorders?

DR WILLIAM G HARDY I seem to have ten points listed for this topic First, it is clear that with the use of a wide variety of techniques (and each of us selects the particular pattern that he finds most rewarding) the function of the peripheral hearing mechanism—the end-organ—can be measured There is a matter of definition here that is apt to make discussion confusing Where does the peripheral mechanism stop and the central mechanism begin? My group has given a great deal of thought to this question, it is not simple Let us assume that the central mechanism begins at the level of the brain stem where one is dealing with audition as a neurally bilateral sequence of events, and that the ganglion-cell structure may be considered in the peripheral mechanism I realize there may be something wrong with this, for we are including the first neural synapse in the end-organ The geography of anatomy is perhaps not quite so important, however, as an agreement on reference In terms of these distinctions between peripheral and central, I believe we have a right to say that there is incontrovertible evidence that the function of the peripheral mechanism can be measured quite adequately

From here on, a clear differentiation of possible pathology is in large part speculative Fortunately, in this regard, one has the opportunity (which he must learn to take) of follow-up, or reassessment, as Dr Goldstein just indicated, to take advantage of comments and observations from the teacher, derived from the child's day-to-day performance A child is exposed to an ordered process of training in class, and it helps a great deal to know what a trained, thoughtful observer sees the child do This kind of information is not available for a two-year-old, of course, but with ever younger age-ranges being admitted these days to special educational situations, the evidence begins to mount up by the time a child is six or seven years old

For many years in our department we have been particularly interested in the use and misuse of galvanic audiometry We find that there are three kinds of patterns relating to the situation *1* the ease and speed of conditioning, *2* the latency of the response, *3* various details of timing involved in the test-picture With relatively few exceptions, when one is dealing with damage to the peripheral mechanism, conditioning is easy, ready, and consistent Latency of response is usually within half a second The requirement of reinforcement may vary considerably So, too, does the nature of the signal Some children respond better to a steady-state tone, some better to a tone pulsed at a frequency of three or four per second With the children whose primary problem turns out to be a language disorder, difficulty in integrating and putting to meaningful use the information presented through the auditory system, the same general patterns exist but with much extension of time It takes longer for these children to be conditioned, and there may be extreme variations in latency of response With the other large group of children who seem to have a central auditory problem, perhaps at the level of the interbrain or the thalamic loops, I doubt that the majority can ever be clearly conditioned One may see responses, many of them, but they do not follow a pattern There is much variety, too, in terms of latency and the details of extinction This is perhaps relatable to the sort of thing currently being demonstrated in clinical psychology as more and more refinements of perceptive modes are studied in older children, some of these are relatable to various signs and symptoms of possible brain-damage, some are not Psychologists use the term *variability* to describe many of the sensory inter-relations of the brain-damaged child, and it is felt that this is a good functional description of some of these central auditory problems The signal, and the information derivable from it, changes, shifts This is inconsistency from the point of view of the tester, variability from the point of view of the subject One wonders what the world of sound is like under these circumstances

When this discussion is finished we can probably all agree that the only really good test of the entire range of hearing, listening and understanding, the reflexes of the auditory mechanism and the integration of the cortical system, is a speech hearing test, but this, of course, remains beyond reach when one is dealing with small children, unless a particular child has developed some language and some useful speech

Back again to the auditory system, there are many interesting observations to be made relative both to loudness and pitch, the two psychological parameters of auditory sensitivity In our observations—and one doubts that the caseload we see is unusual—we find that among the children who offer clear evidence of profound auditory involvement, so much that they cannot possibly learn without the very best of special education, seven out of ten have something more than peripheral auditory lesions In reference here is the preschool-age group Approximately seven out of ten give evidence that their auditory difficulties lie somewhere in the brain stem or interbrain, in the thalamic structures, or in some aspect of cortical relationships

Dr Derbyshire made reference to a kind of "auditory hiatus" in some of these children We have had similar experiences Time and time again, we have tried to condition with a 90-decibel tone without success Then we shift to a 25-decibel tone and immediately get responses Sometimes, after a child begins to respond galvanically, one runs into a gap of perhaps 40 decibels, there are sporadic responses to various tones somewhere near the range of normal threshold acuity, but it requires a signal of 40 or so decibels above this level in order to achieve a consistent pattern of responses This almost forces one to think of some of the auditory problems commonly seen in a child with Rh athetosis Dr Goodhill and others have demonstrated by histopathologic evidence that at least in some of these children the damage may well lie at the level of the auditory nuclei in the brain stem We have examined many such problems, and find that with few exceptions they want much more loudness via a hearing aid or other amplification than does a child or an adult with a comparable pure-tone curve representing a peripheral problem

Some years ago, it became apparent that once there was good evidence of responses in the region of threshold acuity (we are still discussing galvanic skin resistance audiometry), it was profitable to observe reactions to a five- or six-octave pitch-swing at levels well above threshold Some children respond to this stimulus, some do not One cannot pretend to know the details of what this means Where there is a consistent reaction to this changing acoustic event, however, one may assume that it represents an on-going, different event to the child This capacity, we have observed, is commonly not present in children who prove to have extreme central auditory disorders, whether or not this is combined with an aphasoid problem

On the other hand, there is a clear relation between awareness and intelligibility that can be studied, for example, in the problems of geriatric audiology On much less secure bases, one can observe awareness of sound in a child (assuming that there is good evidence of responses within normal range), at much lower levels of intensity than can be used in terms of intelligibility Many older children who have had the advantage of good training in language are aware of sound at much lower levels than they can put to use It may be that a *listening* circuit is involved here

One more point, a matter that we have found confusing In the course of otologic and audiologic history we have all learned to use decibel notation in describing the intensity-loudness factors of an affected end-organ One wonders, however, how anybody can make a statement in terms of decibel notation when the problem lies high in the central mechanism The essence of this kind of problem is that it is not a pattern, it is not a constant, it does not remain "the same", therefore, the idea of describing a child with a central disorder, on the basis of subjective auditory responses, as having a 90-decibel hearing loss, is to my way of thinking absurd This is like taking blood pressure with a clinical thermometer, one might get some sort of a reading, but it would scarcely be descriptive of a dynamic state of affairs.

Dr. Ira J. Hirsh. On this second question, concerning the use of tests for identifying a pathology, Madam Trenque writes—The first question to be answered is, is the lesion situated in the middle ear or in the internal ear? In her first paragraph she points out the well-known observation that when hearing loss exceeds approximately 60 decibels, one can assume that the inner ear is involved. Now, if the deafness is less than 60 decibels, she has suggested that one make a bone conduction examination using conditioning techniques. She suggests also that if the child is not well enough developed to accomplish the test procedure, one can use vocal tests to attempt to resolve the problem. The child who has a transmission deafness, or conductive deafness, will repeat correctly familiar words that he knows, if one raises the intensity sufficiently above the threshold. A child with trouble in the internal ear, even if one raises the intensity far above the threshold, will distort certain words, and the intelligibility will be below 100 per cent.

The manner in which the child has developed language and speech is equally a good indication. If the deafness is severe he will speak very little if at all, and the words that he uses will be simple and childish. If the deafness is less severe, the child will not acquire complicated words. The syntax will be defective and certain consonants will be deformed. The child with a conductive deafness, with onset before the age of acquisition of speech, has a poor vocabulary but good articulation. He presents only a more or less severe language retardation, and in effect he is troubled by a kind of all-or-none phenomenon either the sound is too weak and he doesn't hear it, or it is strong enough and he perceives it without distortion.

As far as indication on the precise etiology of deafness is concerned, in cases of middle ear deafness, these factors are given by other clinical observations than the auditory tests, for example, malformations of the ear, otitis and toxicosis. In case of deafness of the internal ear most of the time the etiology is difficult to establish in a definite manner, difficult to establish with certainty The nature of the auditory residuals and the form of the audiometric curve do not actually permit us to identify the etiology It is possible that the examination of a large group of children where the diagnostic etiology is certain will produce these interesting results in the future

From her own observations, she notes the following that meningitis is followed by rather severe destruction, with almost no hearing residuals or perhaps only islands in the low frequencies Rubella, on the other hand, gives curves situated between 60 and 80 db on the audiogram, and more or less horizontal Hereditary deafness appears to present a polymorphism in audiometric curves Nothing is identified with anything, I presume, in hereditary deafness Within the same family one finds a subject with a falling curve, another with a horizontal curve, in a third, complete deafness

The behavior of the child during the auditory tests very often permits the observation of phenomena superimposed, which point toward a central location for the deafness Such troubles can be motor, mental, psychological The test with a peep show and with pictures, from her point of view, are particularly interesting She gives, third, indications about the development of the deafness Auditory tests can permit us to follow the evolution of the deafness We have thus observed, for example, a functional recuperation of the order of ten or twenty decibels in children submitted to auditory training That is to say, the curve was raised, the threshold was lowered, during the first ten months of training, then it stabilized She has observed also a remarkable stability in the audiometric curves Deaf children whom they have followed are in a large majority those who were believed at first, from otological practice, to have hearing which does not continue to deteriorate

In conclusion, on this second question, the results of hearing tests, oriented toward auditory pathology, are limited, and it is absolutely necessary to supplement these tests in all young children by examining their mental capacity, their language and motor development, and their psychological factors thermometer, one might get some sort of a reading, but it would scarcely be descriptive of a dynamic state of affairs

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The child with a peripheral defect will usually startle fairly consistently to sounds above his threshold The child with a C N S defect may react at first to very weak stimuli, but soon becomes refractory to very intense sounds, or he may not react at all, even to the most intense sounds

If thresholds of auditory sensitivity can be reliably determined, children with peripheral lesions most often will show sloping audiograms with the high frequencies most severely affected Children with abnormalities of the C N S or central nervous system, may have normal thresholds, or frequently, hearing losses of about 60 db for all frequencies

Within any one test the child with a simple peripheral defect will usually show consistency of responses within the limits imposed by his age The child with an abnormality of the C N S will usually not be consistent in his responses, that is, his apparent threshold may fluctuate unpredictably by as much as 30 to 40 db Often it is impossible even to estimate the threshold for this child

A child with a simple peripheral defect is more readily conditioned than a child with a C N S defect to respond voluntarily to auditory signals This difficulty may be carried over into the conditioning of electrodermal responses to sound

In audiometry employing the electroencephalograph, the child with a C N S abnormality may sometimes show normal auditory sensitivity through electroencephalic responses while asleep, even though while awake he does not respond consistently to very intense sounds in other tests The child with a peripheral defect will show the same thresholds through electroencephalic responses when he is asleep as he does through overt responses when he is awake

When there are both peripheral and central abnormalities

DR ROBERT GOLDSTEIN Studies of pathologic anatomy provide us with only limited evidence that results on various hearing tests can be associated with various pathologic conditions This is mostly because studies relating hearing losses to histopathology have been restricted largely to peripheral auditory structures, and then mostly in adults In the studies of pathologic conditions in the central nervous system the accompanying audiologic studies have, in general, been inadequate We can say, however, that loss of auditory sensitivity is associated with organic defects of the auditory nerve and cochlea, problems of language comprehension and production with organic defects of some portion of the central nervous system We have very little knowledge of how much or what kind of central nervous system lesion may be responsible for loss of auditory sensitivity, or of how much damage there is in the periphery in persons with language dysfunction

We have available considerable information about some children, which allows us to compare results of hearing tests with educational progress, with development of skills of communication, and with general behavior In some of these children the pathologic basis of their auditory disorders are quite certain from other neurologic or physical defects, and from medical and developmental histories In the absence of any clearly defined pathologic condition, we can still infer the pathology on the basis of similarities in results on hearing tests and in educational development to children in whom the pathologic bases of their disorders are more certain, and yet, with all this information we cannot say with certainty that the results of hearing tests, or of educational progress, tell us more than *1* there is a reduction in sensitivity to sound, probably from a defect of the peripheral auditory mechanism, *2* there is a disturbance of auditory perception or of linguistic development probably because of some organic abnormality of the central nervous system, or C N S

When we examine very young children we do not have the opportunity to use hindsight from educational development to aid us in determining the nature of their auditory disorders We may have other than hearing tests to help us with our assessment, but let us assume that we must make a judgment on the basis of hearing tests only What kind of information can we get from them to help us decide whether the organic abnormality is in the periphery, in the C N S , or in both? In the limited time available, let us restrict ourselves to generalities, acknowledging in advance that there are exceptions to all of the generalities

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When there are both peripheral and central abnormalities in the same child the consistency or inconsistency with which a child responds may be the most significant differentiating criterion In such instances, however, we must derive additional differentiating information from other tests and observations

Dr Silverman We will refer now to the third question, and that is, what particular testing techniques have you found to be most successful in yielding answers to either or both of the first two questions?

Dr William G Hardy As to the third question, a good part of this has already been discussed Dr Goldstein just added more by implication I should like to make a few more observations

I believe we have all learned over the course of years that a fundamental technique is to get the clearest kind of evidence we can from parents who are thoughtful, careful observers Oftentimes we find that when we work with parents who have been thoughtful and clear in their observations, much of the clinical fancy-work that we do is simply corroborative

In the course of time we have come to value extremely highly the parents' answer to a simple question that has to do with the child's development, it produces particularly good dividends when there are other small children in the family "When this baby was three or four months old—not more than that—did you have any question about his hearing?" Oftentimes, when the ultimate picture indicates an aphasoid disorder, they answer "No" Oftentimes, when there is a severe central aberration of one sort or another, the answer is clearly "Yes" Oftentimes, the parents had not observed anything untoward, but this negative fact, itself, is important What we want to know, of course, is what can appropriately be called an auditory orienting reflex which should be present in infants who both receive and perceive sound

We like to see what children do in a controlled sound field, under highly structural circumstances, and watched by at least two trained observers Many kinds and levels of noise and sound are employed, the general type and range of which is clearly known Now, a three-month-old child does not wave his arms around and point to the sound-source, but one can see all sorts of reflexes and reactions, often localization, sometimes an interruption of his activities This last is a kind of negative response which, I believe, is entirely valid when judged as a reaction Usually, when we see these responses, and help the parents to recognize them, we return to some of the details of parental observation and jog their memories a bit Thereafter, they come through with many more comments of their own about things they have seen the child do, but have not believed their own eyes, because somebody had told them that their child was deaf This, to most parents, means a total thing (rare, indeed), so they stop expecting the child to respond to sound

I feel that I must take sharp issue with Dr Trenque, *in absentia*, on the etiology and the presumed fact of total deafness, because, from her description I do not know what she means by deafness We see hundreds and hundreds of post-meningitic children over the years, and I do not remember one that was totally deaf in the sense of complete loss of auditory reflexes For the most part, I believe, this business of the total, bilateral destruction of the peripheral mechanism is a thing that belongs in history Medicine in the past 20 years has changed all this considerably We are all well aware of the total involvement of unilateral impairments from various causes, but bilateral destruction is something different Of course, in an isolated instance, meningitis can still result in this but, fortunately, in communities with good medical care a child does not go two weeks without hospitalization and diagnosis If he did, one suspects, he would probably emerge totally deaf now, as he used to

I shall not say anything more about galvanic audiometry Our views on that are well known in the literature We are beginning to work seriously on E.E G audiometry, which has great possibilities, not only in measurement of function but also in furthering information about specific sites and modes of neuro-physiologic dysfunction Let me return to a comment made before. If one is dealing with a child who has some language and speech, the real point is a thorough test of speech-hearing. This, too, needs to be believed. A child who gives a subjective pure-tone audiogram of approximately 80 db in the speech-hearing range, but who then demonstrates a speech-hearing threshold as good as 40 decibels, is not an educatively deaf child. Another small note of warning: we see many children in the course of a largely consultative service who apparently have central auditory disorders, but who have been forced to use the heaviest duty hearing aids with maximum gains. They have not wanted these aids, for the obvious reason that they have been given too much sound. This warning will bear reiteration, for it is something about which great care must be taken in the field. At stake here, in part, is a wide-eyed acceptance of a concept of deafness as a total kind of behavior, as though one were talking about a specific entity, always related to the same tissue, the same tissue-damage, and the same dysfunction. It is extremely important in dealing with young children to determine whether the problem is peripheral or central, or combined—whether it involves both hearing and listening, or something else entirely; we also find—and believe that this is sensible practice—that oftentimes when one is quite sure that the peripheral mechanism functions fairly well and that there is evidence of a central involvement, a very mild-gain hearing aid may be salutary, largely as an attention-centering device. This is a matter of judgment and experience, not only in terms of a test-picture but also all the rest of the picture which, to us, involves a most thorough otologic, pediatric, neurologic and often psychiatric appraisal.

We were asked to discuss hearing tests. One idea that has emerged from this discussion is that everybody who has spoken on these topics has agreed that hearing tests alone are not sufficient to describe these problems; more than that, that any one hearing test is totally inadequate to describe even a major part of the functions that relate to what I have been calling "reflexive hearing."

Just two more points. I should like to commend attention to Dr. Derbyshire's use of the term *aphasoid*. This is a good term, because it does not have a direct relationship with the classical neurologic history of the *aphasia* that many of us have lived with More than that, it stresses the idea that we are not dealing with a little category of specific damage that can fit into a cubby-hole, the "oid" simply means *like* When a child is described as aphasoid in behavior, the describer is on safe ground, because he is presumably saying that the main trouble is not auditory, and that he wishes he knew better how to describe what is wrong with him

This world of ours needs to wake up to the needs of children who have these diverse, diffuse central language disorders, with or without central or peripheral auditory disorders Some of you gentlemen here at the Central Institute for the Deaf may forget that you are sitting in the "angel's chair" You have a curriculum and a faculty capable of moving a child back and forth, at need, from one stream of training to another To my knowledge, there are precious few other places in existence where this second problem, this aphasoid behavior, is even recognized, let alone where somebody is trying to do something about it

Dr. Ira J Hirsh The usefulness of the test depends more on the method employed than on the particular test technique Auditory tests alone are incapable of resolving the problem as the risks of error are too great Auditory tests must be included in an ensemble of tests We ourselves proceed in the following manner in the first place, we make a very complete interrogation of the parents on the history of the child's genetic development, his motor behavior, his emotional, sensory, and intellectual behavior, the development of his language, and his family In the second place, we study the mental age of the child There exists in France a battery of non-verbal tests, established by Madame Borel-Maisonny, that we consider sufficient for a primary discrimination What we wish to know here is whether or not the child has a substantial mental retardation, and whether he is capable of accomplishing the audiometric tests In the third place, we study his language This language evaluation has two objectives first, to analyze difficulties in the language behavior itself The alterations in language can be subsumed under two groups of phenomena First, the tonal quality of the voice, the rhythm and articulation, when these are very altered the child's language is only a babble, (French, charabia), only once in a while modulated by a recognizable word. The second concerns the understanding of words and their memorization, changes in syntax and automatic responses and verbalizations. The first category is the fact of peripheral deafness, and the second indicates disorders of central origin.

Fourth, we proceed to the auditory tests. We always use tests with noise, or pure tones, and the spoken voice. The principal basis for the voice tests, to which we attach great importance, is the utilization of responses that the child already has, and these can be established in collaboration with his parents. Can the child respond to his name, some words that he seems to understand, what are some of his vocalizations, the words that he can pronounce and others that he can understand? The tonal test that we find most useful is the peep show, because it can be used relatively early, in certain intelligent children at the age of three years, in others at four years of mental age. This age is precisely the one at which we wish to begin intensive training. The second reason for using the peep show is that it is very precise. Our experience in this area is abundant. We have been using it for seven years. Third, the behavior of the child during the course of the test is rich in revelations of his own character and capacities for attention, self-control, comprehension and emotional behavior.

Among the vocal tests our preference is for a test with pictures. We have assembled a large collection of pictures, among which we always find objects or animals that are interesting to a child. We name them with a term that he uses himself, or that he can learn. If a child does not speak, but is capable of designating these objects with some name or other, even though incorrect, this name is used in the test. The test permits us to learn very rapidly the capacities both for hearing and for lipreading in the child.

DR. ROBERT GOLDSTEIN. For every child we try to get as much information as possible from extensive case histories, from psychometric examinations, from neurologic examinations when possible, and from careful observations of general behavior For today, however, I shall limit myself to the usual kinds of hearing tests we use to learn the nature of auditory disorders, in order to make educational recommendations

In all of our hearing tests we look for at least two things one, the weakest sound to which a child will respond, that is, his threshold, two, the manner in which he responds to sound

First of all we look for overt reactions to sound, either startle responses or voluntary responses Ordinarily, it is difficult to obtain startle responses at a child's threshold, but if we begin with weak sounds first and gradually increase the intensity, we may get the first reaction close to threshold Almost any child will cease to react to the same kind of sound, even at high intensities, if that sound is repeated frequently Variation in the kind of stimuli does much to delay this adaptation to sound The child with a C N S abnormality tends to ignore sounds sooner than the child with a simple peripheral abnormality

Whenever it is possible, we attempt to condition a child to make a voluntary response, such as removing a peg from a board when he hears a sound The child with an abnormality of the C N S is much more difficult to condition than a child with a peripheral defect In any case, we extend ourselves as much as possible to condition a child in order to get him to respond at the limit of his sensitivity

When our findings on the basis of overt behavior are too vague to be dependable, we try to determine a child's auditory threshold indirectly by using electrophysiologic reactions to sound as indicators of "hearing" We attempt to condition electrodermal responses, better known to you as GSR, to sound with electric shock as the unconditioned stimulus Or we examine electroencephalic responses to sound, that is, changes in the brain waves in response to sound while the child is asleep We do not attempt to condition electroencephalic responses In both electrodermal and electroencephalic audiometry we try to be as objective as possible in our judgments of electrical responses, which we analyze, by the way, only after our test is finished, however, we do make note of any overt responses during our tests

As in the case of conditioning voluntary responses, it is generally more difficult to condition electrodermal responses to sound in children with C N S defects than in children with peripheral defects This is by no means a clear differentiating criterion because there are many deaf children and many normal children who are also difficult to condition

In our brief experience with electroencephalic audiometry we have found that it works as successfully with the children we call aphasic as it does with deaf children We see on a few occasions that children with C N S abnormalities give responses to significantly weaker sounds than ever consistently elicit voluntary or electrodermal responses Ordinarily, though, there is good agreement among all tests as to threshold of auditory sensitivity when there are reasonably consistent responses in each of the tests

Sometimes we are successful in determining auditory thresholds by these indirect techniques, and sometimes we are not Most often, however, we get enough information to confirm, at least partially, what we are able to observe in the overt responses

In general summary, we try to condition voluntary responses to sound whenever possible and rely on startle responses when we cannot condition a child We push to the limit of auditory sensitivity but we note responses to supra-threshold stimuli as well, as indication of a child's ordinary reaction to sounds We attempt indirect determination of thresholds through electro-physiologic responses to sound when we cannot obtain reasonably consistent overt responses The child with loss of auditory sensitivity because of a defect of the auditory nerve or cochlea, that is, the deaf child, usually conditions fairly easily within the limits of his age, is reasonably consistent in his responses, and usually shows a greater loss of sensitivity for high frequencies than for low frequencies The child with a defect in auditory perception and in linguistic development, because of some C N S abnormality, is more difficult to condition, is usually inconsistent in his responses, and most often shows no loss or only a moderate loss of sensitivity

DR. SILVERMAN Dr Myklebust will give his answers to the questions in a single presentation

DR. HELMER MYKLEBUST Emphasis on the ways in which hearing tests can be useful in making educational recommendations is highly desirable Often hearing tests have been analyzed in terms of their significance in psychophysiology without reference to the implications of the results for the child's education and general adjustment When we study the objectives for appraising a child's auditory capacities we find there are at least three basic goals (a) to determine the type or nature of the auditory incapacity, (b) to determine the extent or the degree of the defect, and (c) to ascertain the site or sites of the lesion This is shown schematically in Fig 1

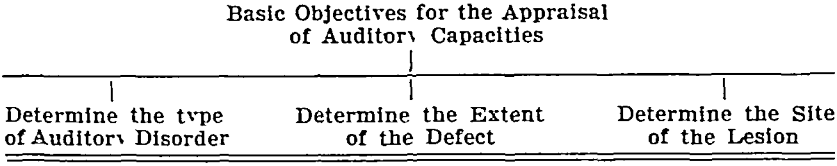
Basic Objectives for the Appraisal of Auditory Capacities
Determine the type of Auditory Disorder
Determine the Extent of the Defect
Determine the Site of the Lesion

Fig 1.

The Primary Types of Auditory Disorders

Peripheral Deafness	(End Organ)
Central Deafness	(Auditory Pathways)
Psychic Deafness	(Mental Illness)
Perceptual Disorder	(Listening Defect)
Receptive Aphasia	(Language Disorder)
Auditory Agnosia	(No Sound Meaning)
Overlapping Conditions	(Multiple Disorders)

Fig 2

There are six conditions encountered in the appraisal of auditory disorders in young children, as shown in Fig 2 The seventh possibility is that more than one deficiency is present, necessitating the determination of overlapping conditions

Peripheral deafness refers to end-organ defect Central deafness means that the auditory pathways in the central nervous system have been impaired and that the nerve impulses do not reach the interpretation area in the auditory cortex This impairment falls essentially between the cochlear nuclei and the medial geniculate bodies

Psychic deafness is the condition whereby the child has adequate capacities organically but rejects sound for reasons of emotional disintegration It is our experience that psychic deafness in young children occurs mainly in psychotic children, but might be present in the severely neurotic

Receptive aphasia occurs as a result of damage to the interpretation area in the temporal lobe It is a symbolic language disorder and is present with considerable frequency in young children

Auditory agnosia refers to the condition resulting from gross damage to the auditory cortex Apparently this condition occurs only rarely When it is present the child cannot attach meaning to any sound although he has normal hearing acuity

Auditory perceptual disorders are complex and may affect the normal auditory process in various ways Figure-ground may be disturbed with the result that the child cannot use the auditory field selectively, thus, he can hear, but he cannot listen Auditory memory and discrimination also may be involved

Overlapping conditions refer to the presence of more than one defect Perhaps one of the primary problems relative to hearing impaired children is the multiple handicap of hearing loss and brain damage

Complete auditory appraisal assumes that each of these conditions has been considered and that the specific type of auditory disorder has been determined

Now we come to the second major objective, the determination of the extent or the degree of the defect If peripheral deafness is present it is essential to ascertain the degree of the hearing loss For educational purposes the most significant single factor in this connection is the extent to which the deafness has affected language acquisition and usage Four major classifications of degree of deafness relative to educational recommendations are shown in Fig 3

Children with a moderate hearing loss do not require specialized educational procedures Their language abilities fall within normal limits Those who are severely hard of hearing require special educational methods, but they benefit substantially from the use of amplification The profoundly deaf child seems to gain very little educationally from amplification, and thereby is dependent upon the specialized techniques developed specifically by educators of the deaf The deafened child is one who has sustained profound deafness after five years of age and thus retains his language abilities, when profound deafness is sustained prior to five years of age usually the language which had been acquired is not retained

The Degree of Deafness

Hard of Hearing (Moderate)
Heard of Hearing (Severe)
Profound Deafness
Deafened

Fig 3

The Site of the Lesion in Auditory Disorders

External Ear	(Atresias)
Middle Ear	(Conductive)
Inner Ear	(Nerve-cochlear)
Auditory Pathways	(C N S)
Auditory Cortex	(Temporal Lobe)

Fig 4

The third primary objective of the auditory appraisal is to determine the site of the lesion Five major sites of lesions to be considered in appraising auditory capacities are shown in Fig 4

Lesions of the external, middle, and inner ear traditionally are determined by tests of acuity, using the bone and air conduction methods. The most common type of deafness in young children is that which results from deficiency in the inner ear. Frequently, inner ear lesions can be predicted from the degree of the hearing loss; when losses of 60, 70, 80 db, or more are present it is apparent that the loss does not derive from a simple conductive involvement. Lesions of the central auditory pathways and of the auditory cortex are more difficult to determine objectively; however, some test suggestions are given later.

Age of Onset of the Auditory Disorder

Prenatal Period	(Before Birth)
Pre-speech Age	(Birth to 2 yrs.)
Early Language Period	(2 to 5 yrs.)
Late Language Period	(After 5 yrs.)

Fig. 5

Etiological Classification of Peripheral Deafness

Endogenous—(All hereditary)	22.6%
Exogenous—(All non hereditary)	
(a) Meningitis	11.3%
(b) Other diseases	27.8%
Undetermined (Unknown)	38.3%
N = 822	100 %

Fig. 6

Two other significant determinations from the point of view of educational recommendations are the age of onset and etiology. These do not derive directly from the auditory test itself, but they are factors that must be considered when interpreting the results. The importance of age of onset is indicated by the different nature of the educational recommendations when deafness is sustained in the pre-speech age, or after five years of age. The importance of etiology is indicated by the higher incidence of multiple handicaps, such as deafness and brain injury, when the deafness results from rubella, meningitis, or certain other diseases. The primary classifications of age of onset in young children are shown in Fig. 5.

The primary etiological classifications are shown in Fig. 6.

That etiological factors are significant in terms of educational recommendations is apparent from the fact that research reveals significant differences between the exogenous and endogenous in such areas as intelligence, motor capacities, and educational achievement.

No one test of auditory capacity can satisfy all of our demands or goals. Actually three essentially different types of tests are required. This is illustrated in Fig. 7.

Diagnostic Appraisal of Auditory Capacities

Peripheral Nervous System—End-Organ	Central Nervous System C.N.S. Pathways and Auditory Cortex	Psychological Integrity Mental and Emotional Processes
Auditory Acuity ↔	Integration and Use ↔	Psychic Auditory Behavior
) Conditioned play audiometry	(a) Listening Tests	(a) Scanning Tests
) Sound field speech, gross sounds and pure tones	(b) Localization Tests	(b) Foreground background
) PGSR	(c) Perceptual Tests	(c) Vocal monitoring
) EEG	(d) Language Tests	(d) Imitation and Echolalia
) Behavioral Symptoms	(e) Pain Sensitivity Tests	(e) Comprehensive-Selective
	(f) Behavioral Symptoms	(f) Behavioral Symptoms

Fig. 7

Most tests provide relevant information concerning the integrity of all three of these avenues. For example, if a child is difficult to condition, either with PGSR or in conditioned play audiometry, there is a presumption that even though he might have a hearing loss, he is also brain damaged, mentally ill, or mentally deficient; however, some tests are more useful than others for ascertaining a specific type of integrity. We have found listening tests to be highly useful in the study of children presenting problems of the brain damage type. In general, receptive aphasic children have auditory perceptual disorders, and thus cannot give the sustained attention required in listening. We are in the process of standardizing a battery of auditory perceptual tests on normal children and those with auditory disorders, and these tests show promise for use in diagnosis The implications of this study are shown in Fig 8

Normally we select sounds from the auditory field according to organismic exigencies at any particular moment This is illustrated by the arrows showing normal shifting of figure-ground We see also that a basic function of background hearing is scanning of the environment in order that the organismic homeostatic relationships can be maintained In contrast, foreground hearing serves the basic purposes requiring listening, especially for the purpose of communication

Auditory Perceptual Functioning and Figure-Ground Behavior

Background Hearing	Normal shifting of ←——→ Figure ground	Foreground Hearing
Mandatory scanning of environment		Listening
Signaling warning		Receptive language
Homeostatic awareness		Immediate needs of the organism

Fig 8

In general, study of young children having auditory disorders suggests that they fall into groups on the basis of their auditory perceptual behavior Those having impaired hearing lose the background function of hearing and, therefore, are restricted to foreground hearing In psychic deafness the child relinquishes inter-personal relations by rejecting foreground hearing, but he retains the more peripheral or primitive background use of hearing The brain damaged child cannot structure the auditory world, so he is a victim of the entire sound field He cannot select an appropriate sound and attend to it to the extent that the organismic needs are achieved satisfactorily In a recent publication Dr Neff reported similar behavior in cats after ablation of parts of the auditory cortex

The child with central deafness seems deficient on tests of localization, this is in contrast to those with peripheral deafness, furthermore, these children seem to be reduced in pain level responsiveness They might have normal acuity by PGSR but do not have ability to monitor their vocalizations

A number of other characteristic responses might be given

Psychic deafness in young children frequently can be determined most satisfactorily by informal tests, or by a combination of formal and informal techniques Because these children tend to reject foreground hearing the test which is limited to background responses is most suitable Conditioning techniques frequently are unreliable with this group Tests requiring scanning of background, monitoring of vocalization, and selective comprehension have been helpful in ascertaining whether such children have normal hearing and are rejecting sound for emotional reasons

In young children presenting complex auditory disorders the hearing test alone frequently does not make it possible to make a differential diagnosis Often psychological, psychiatric, and neurological study must be included The total maturational aspects and the behavioral symptomatologies are critical factors

Of a group of 325 pre-school age children with auditory disorders there were eighty with peripheral deafness, sixty-eight with deafness with central involvement, one hundred and forty-two having aphasic and other types of central involvement, twenty-four with psychic deafness, and eleven mentally deficient A revealing aspect of this study was the high incidence of children having both deafness and brain injury and the slightly higher incidence of children having auditory disorders other than peripheral deafness This seems to us to highlight the importance of differential diagnosis and the implications for educational recommendations

DR SILVERMAN What we shall do first is to ask the panel to react with each other

DR HARDY Considering the independence of this group, I think there is a tremendous unanimity involved I do not know where Dr Hirsh stands I am becoming increasingly concerned about the use of the term "brain-injured" as a genetic reference to so many of these problems We see many more children who get that way from pre-natal events of one sort or another wherein there is no exterior evidence of injuries Neurologists examine these children and keep telling us that they can see no other evidence of brain injury, and our psychologists keep saying they can see no other particular evidence determinable except auditory perception

You have to be very careful about this concept so that it does not become a label attached to many of these children, because, in all truth, ninety-nine per cent of our school people will not accept a "brain-injured" child, whereas a deaf one is all right I would like to know what the panel thinks about that

DR MYKLEBUST Well, I might say that I quite agree that we need a better term, also, that, as we use the term, we do mean central involvement, not necessarily literally an involvement of the damage type It is entirely possible that some of these are biochemical, of course

I would like to comment on the latter part of Dr Hardy's comment just to this extent, that I suppose, central involvement, or damage, whichever kind of term we are going to use, is in the state today where there is no one key to it Sometimes the EDG shows it, sometimes a neurological shows it, sometimes the psychological shows it, etc Certainly, motor tests and other tests of this type are frequently useful in bringing this into the foreground It is essential that we use a multiphasic approach of study to this condition at this time

DR GOLDSTEIN I would like to make two comments about the use of the word or term "brain-injury", one is that I am in partial agreement with Dr Hardy that a person can have organic injury to the brain and have no obvious problems in communication He may have perfectly normal hearing, speech and language A person who does have problems in communication that cannot be attributed to a loss of sensitivity, to mental deficiency, or to psychic disturbance, may very well have a language disturbance of some sort presumably due to some abnormality of the organic central nervous system, in fact, we have enough indications to accept the aphazoid or aphasic behavior as a symptom of some central nervous system abnormality

I have a greater objection to the word "brain-injury" in parallel with the term "deafness" I think we should say either "ear-injury," "brain-injury" or "deafness" and some other language disturbances

DR HIRSH Dr Trenque has written a summary page which she entitles "Reflections on the Problem of Auditory Testing of the Young Child, and the Data that such Tests Supply"

At this stage of our experience, we consider that there are two categories of children relatively easy ones and difficult ones The relatively easy ones are the following First, purely deaf children, that is, children who are only deaf without other deficiencies superimposed One knows now the behavior of purely deaf children, their characteristic difficulties, and the retardation that follows the deafness in intellectual performance The diagnosis is fairly easy, and the measure of the amount of deafness can be established with precision after the age of four years The second category of relatively easy cases are mental defectives These are equally easy to screen It is more difficult to say whether a partial deafness is supplemented by mental retardation

The difficult cases are composed of the following groups children who have important psychic difficulties, aphasic children, deaf children with an intellectual or psychic deficit In our opinion, only a prolonged observation will permit the establishment of a diagnosis or prognosis that is precise Compensation for deafness depends essentially upon mental capacities and the social adaptation of the child One can only hope, even after a complete test of hearing, intellect and psychology of the child The real capacities for overcoming deafness cannot be appreciated definitively even in the course of the first stage of education, that is, at the acquisition of concrete vocabulary, reading and writing, but only after the child has acquired more complex notions of time, cause, attributes, etc

DR MYKLEBUST I think there is perhaps more agreement on this question than we had anticipated I suppose I could raise the question now as to whether we can classify children telling us that they can see no other evidence of brain injury, and our psychologists keep saying they can see no other particular evidence determinable except auditory perception

You have to be very careful about this concept so that it does not become a label attached to many of these children, because, in all truth, ninety-nine per cent of our school people will not accept a "brain-injured" child, whereas a deaf one is all right I would like to know what the panel thinks about that

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We should give our audience an opportunity to direct questions to any member of the panel

DR HIRSH I apologize for not being able to defend some of Dr Trenque's points here There were certain paragraphs in which I panicked before I got to the end, and this will be published in full when we publish the proceedings I thank Dr Bocca, who brought Dr Trenque's paper here He has seen her recently, and perhaps, from the discussion that comes from the floor he may wish to make a comment or two as to his reflections of her point of view on these matters

DR BOCCA I have no comment

DR SILVERMAN We shall now give our audience an opportunity to direct questions to any member of the panel

DR BRUCE M SIEGENTHALER I would like to direct a question to Dr Myklebust In your last slide you showed the results of the classification of three hundred and some children Will you comment as to what general population that has been drawn from? What are the factors that led to picking out these particular three hundred and twenty-five children?

DR. MYKLEBUST That is a very good point I am glad it comes up because I meant to mention, that this is a selected sample This is a sample of children who come to a hearing diagnostic center in a medical school They are definitely selective factors They have come there because they have very real problems

DR. SILVERMAN May I ask a question do you think that because we become interested in a certain kind of child, we may be looking at a very obscure sample in the way we operate?

DR MYKLEBUST I would agree with that entirely, and we must be careful about selected samples That is why, in another survey which does include children throughout the nation, we have stratified samples from all types of schools and age levels and so on I think it is a very important question I think it is very important to mention that the data there necessarily represent the basic things having certain kinds of language disorders as aphasic I find it difficult to see why we should not do so if the condition is comparable to that traditionally referred to with adults I do not see why we should confuse age of onset with classification The fact that the child sustains this prenatally or at the time of birth does not alter the basic classification

In deafness we specify early deafness by congenital deafness, in psychiatry, they use the term schizophrenia Childhood aphasia I wonder what you think about that

Dr Goldstein I would like to speak in support of that comment I think that simply because the term "aphasia" grew up around adults does not make it the particular property of adults People have objected to the use of "aphasia" in children because of the obvious differences in behavior of the adult aphasic They say that the person who has sustained an accident is so different from the child who never developed language, but, have you ever stopped to compare an adult who suddenly loses hearing to a child who never had any hearing There is a tremendous difference in many aspects between these two people, and yet, if they have certain symptoms in common, we have no objection to calling the adult "deaf" and the child "deaf"

Dr Hardy I object to calling either of them deaf Let us consider how much hearing they have

I would like to play along with this idea of childhood aphasia with a proviso or two first, the field of neurology is beginning to learn what we are talking about in terms of functional and developmental aspects of these problems I am not sure that is a general truth at present, second, everybody who addresses this concept of childhood aphasia really makes a serious effort to include and distinguish this business of auditory perception or imperception and stop talking about, let's say, a peripheral child with aphasia The only qualification is that these things be made inclusive and exclusive in one way, whether one is discussing auditory information as the lack of development, or damage to the centers which have to handle that information as the lack of development, and how these two get together perhaps not so true of the individual with the difference in the two ears

It seems to me that it is something worth watching and worth testing for increasingly I think we have a great deal to learn with this localization and its validity and reliability and so on We do feel that there is a correlation between it and damages that cannot be explained on the basis of peripheral involvement

DR HARDY Dr Trenque agrees with that observation I should think that where there is a profound involvement this would not be too critical a point, because, it is our experience that when it is profound, either peripheral or central, it is bilateral, both sides are involved Oftentimes there are conductive lesions, or acute otitis more severe in one side or the other

This business of undertaking audiologic appraisal of these young children without a full foreground and background of the best possible work is for the birds, as we may say You have all the information possible about the organic state of the child I think that would tend to direct the thinking

MR JACK ROSEN I am particularly pleased to have so much attention called to the central problems, but, at the same time, I would like to call attention to the fact that there is no law which requires that a child have only one problem, even if there were, children would not obey it

The purpose of this remark is that the central problems are determined upon the basis of symptoms which are not auditory for the most part It is quite possible, and in fact, very often it does occur that children do have hearing losses and some of these other symptoms at the same time There is a tendency, when attention is called to a new phenomenon, to disregard some of the older phenomena and techniques, and I would be particularly concerned about the neglect of careful audiological evaluation before deciding that a child has only a central problem or only a psychic deafness, because this can lead to serious problems I would also be very care-

DR R N REILLY During the discussion of the successful techniques none of the members of the panel have mentioned the question of frequency modulation in testing young children When I was in the Netherlands three years ago, Dr Huizing was using frequency modulation in testing babies and young children, and during the past six months I have used it with quite a good deal of success I wonder what the comment of the panel would be in relation to that?

DR HARDY I think, Dr Reilly, that this simply reflects the time We have used frequency modulation for six or seven years as part and parcel of the pure tone presentation in subjects It is a wonderful attention centering device and oftentimes, as you play back and forth between a steady pulse tone and then introduce modulation, you get responses you cannot get otherwise, particularly with C N S involved children, I think

DR MAURICE H MILLER Dr Myklebust mentioned that the child with a central disorder will have difficulty, or may have difficulty, in localizing sound Will not a child with a peripheral problem also have difficulty in localization if there is a large difference in the acuity between ears, and is this not a factor of the difference between ears rather than with the site of the lesion?

DR SILVERMAN May I repeat the question The question is first in the form of a comment that Dr Myklebust indicated that difficulty in localization might indicate a lesion of the central nervous system Dr Miller raises the question as to whether that might not be true of end-organ or middle ear deafness, for that matter, and may be related to a difference in sensitivity in the two ears

DR MYKLEBUST Yes, of course Difference of degree of involvement of the two ears might very well be affecting localization response As such, we can do nothing but accept it and entirely agree that it is a very real possibility

I suppose I am referring to something more like this, that in certain children, and this is not specifically those with, let's say, a simple peripheral involvement, not only do they not localize, but they do not attempt to localize This is perhaps not so true of the individual with the difference in the two ears

It seems to me that it is something worth watching and worth testing for increasingly I think we have a great deal to learn with this localization and its validity and reliability and so on We do feel that there is a correlation between it and damages that cannot be explained on the basis of peripheral involvement

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DR SILVERMAN I shall now attempt to summarize the panel deliberations

The panel directed its attention to three questions one having to do with the goals set, particularly with reference to educational recommendations and the testing of the hearing of young children, two, the evidence for the results of hearing tests that can yield information about the pathology or auditory and other disorders, and three, what particular techniques are used

The panel seemed to be concerned with the differentiation of end-organ from other types of lesions, and at one time seemed to work on the anatomy, another time on the dimensions of behavior, and still another time on the dimensions of ease of conditioning

They seem to go from one to the other, and they seem to admit that it was difficult to follow the outline In one case we got the words "conductive" and "language" in the same column, and in another case we get a little bit of anatomy and behavior in another column, but this, again, is a matter of groping for the universals to describe certain kinds of conditions that are observed

There seemed to be unanimity with what was stated so succinctly by Dr Trenque, that there are easy and difficult cases What we are trying to do, apparently, is to supplement what seems to be a good deal of clinical artistry All of this is involved We have to develop more objective techniques

One thing surprises me, however, about the statements of the panel here, or one omission—and I know they are aware of this—and that is the validation of some of the statements that have been made For example, from the audience there was a comment about a test's being good What are the dimensions of goodness in terms of the behavior of the child as he develops?

I also was surprised that there was as much agreement among the people. I looked forward to bringing them together, and I am delighted that we have had this opportunity to have all of them I express our gratitude

II DIAGNOSIS OF HEARING DISORDERS

After a brief recess, the International Conference on Audiology reconvened in the Auditorium of the Washington University School of Medicine, St Louis, Missouri, Dr Ira J Hirsh, presiding

DR HIRSH We will now continue this afternoon's symposium on the Assessment of Auditory Function We have discussed so far tests appropriate to young children, and now we propose to approach an area that represents probably the closest connection between the disciplines of otology and audiology

AUDIOMETRY IN DIAGNOSIS

RAYMOND CARHART,

Evanston, Ill

I

The subject of audiometry in diagnosis has no many ramifications that one cannot hope to discuss it fully in a single paper, moreover, the subject is one to which both research and clinical contributions are continuously being made, so that any review one undertakes today will seem inadequate tomorrow Realism requires that the present discussion be restricted appropriately

To this end, only the relationships between measurement of thresholds for pure tones and diagnosis of hearing disorders are here considered. The importance of speech audiometry, the significance of supra-threshold function in response to pure tones and to noise, and the value of special techniques, such as psychogalvanic audiometry are obvious. Each of these topics is worthy of extensive coverage, but the present discussion is arbitrarily restricted to a review of major principles in interpreting conventional threshold audiograms and to an examination, through examples, of the fact that the formulation of additional principles may be anticipated.

II

The air conduction audiogram conveys substantial information of diagnostic importance.

For one thing, air conduction curves are sufficiently typical in some types of hearing loss so that the audiometric pattern suggests a possible etiology to the clinician. The most obvious illustration of such a situation is the notched curve showing loss for high frequencies, which leads one to suspect noise-induced hearing loss. Another example is the gradual deterioration in acuity for higher frequencies so characteristic of presbycusis. In contrast, there is the relatively flat loss of about 50 db which is slightly more pronounced for low frequencies than for high frequencies. Such a curve is likely to result from marked stapes fixation, from certain other conductive lesions, or from labyrinthine hydrops, if it is of the sensori-neural variety. Again, a trough-shaped audiogram which tends to follow an equal-loudness curve, *i.e.*, an equal phon contour, immediately suggest the possibility of a non-organic hearing loss; thus, while threshold pattern alone never allows definitive diagnosis, the details of the air conduction curve often contribute to such diagnosis. It is, therefore, pertinent to continue an interest in the types of curves which categorize varieties of hearing impairment, and to seek further insight into the inter-dependencies between the two.

As a corollary to the foregoing observation, the relationship between the two air conduction curves obtained from a single patient tends also to distinguish varieties of hearing loss. Bilaterally symmetrical impairments are relatively common in some conditions, such as in endogenous congenital losses, and in presbycusis. Moderate dissymmetry of loss is usually observed in other conditions, for example, in hearing losses due to anoxia at birth, or to otosclerosis Other pathologies most commonly affect hearing in one ear primarily or exclusively One illustration is the complete unilateral destruction of auditory function which mumps sometimes cause Similarly, acoustic neurinomas, temporal bone fractures, and sudden vascular disturbances usually are unilateral and, hence, effect audiometric results in only one ear Again, cases with labyrinthine hydrops often show depressed hearing in only one ear, although this condition may manifest itself bilaterally, and hearing loss tends to fluctuate markedly In consequence of tendencies such as those just mentioned, the clinician can frequently utilize his observations on the audiometric balance between ears as a helpful segment of the information he requires in order to reach his diagnostic judgment

III

The fact that the relationship between air and bone conduction thresholds assists in distinguishing sensori-neural involvements from lesions in the external and middle ear is, in the minds of many people, one of the most important diagnostic applications of pure-tone audiometry The principles involved are generally accepted It is clearly recognized that adequate determination of bone conduction thresholds requires precautions of calibration and of test administration beyond those which are necessary for good air conduction audiometry When such precautions have been taken and the patient has an organic loss, the general level of the bone conduction curves indicates the degree of sensori-neural involvement (without distinguishing between cochlear and retrocochlear sites) If the air conduction curve lies at the same level, the total loss may be judged as sensori-neural By contrast, there cannot be a sensori-neural involvement when acuity by bone conduction is normal Here, any substantial depression of acuity for air-borne stimuli must be due to a lesion in the transmissional system In other words, such a relationship indicates a conductive loss The third alternative is the condition where both bone and air conduction curves are depressed, but where the loss by air is significantly greater than by bone In such an instance, the depression of the bone curve bespeaks a sensori-neural component of loss, while the further depression in acuity for air-borne sound is evidence of a concomitant conductive, or a transmissional, loss One is here faced with a composite loss or, as some would still term it, a mixed loss

IV

In recent years it has become increasingly apparent that the clinical audiogram contains a host of subtler clues which can contribute to finer diagnostic differentiation A few of these are currently known, as is illustrated in the subsequent sections of this paper It is imperative to remember, however, that the clinical audiogram contains additional clues Some of these await discovery, while the significance of others needs clarification The generalization which must be stressed at the outset is that clinicians have tended to discount subtler configurational features of the audiograms at their disposal and, hence, have failed to gain full benefit from these test records True, much research is needed to catalogue all the aids to differential diagnosis which reside in good clinical audiograms For the moment, however, the important points are that known clues are not being used fully, and that clinicians, on the whole, are not actively curious about the less obvious significance of the pure-tone audiogram

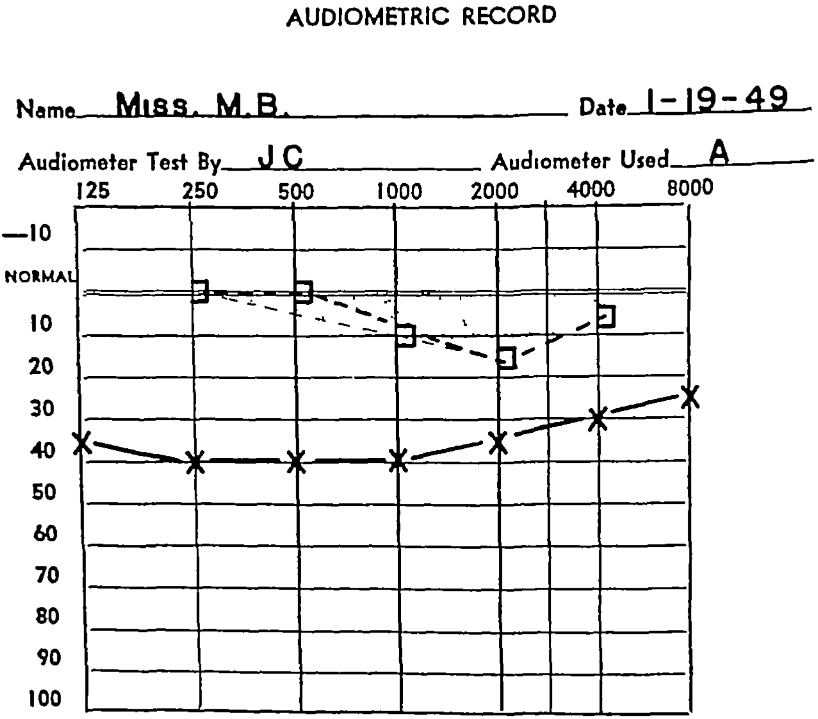
V

Particularly good illustrations of subtle audiometric clues are found in the bone conduction curves characterizing different kinds of transmissional deafness Mechanical lesions tend to cause distinctive distortions in bone conduction audiograms These distortions are slight, and they are due to changes in the physical constants of the auditory system rather than to modifications of sensori-neural activity In other words, the effective agitation reaching the organ of Corti from a bone conduction oscillator can be influenced to a measurable degree by the condition of the middle ear and of the external ear

Fixation of the stapes, for example, induces such mechanical modification in the bone conduction audiogram Fig 1 presents a record which is characteristic of this condition The patient involved was diagnosed as having clinical otosclerosis without secondary nerve degeneration For sake of simplicity, the responses for only one ear are shown in the figure The significant feature of this audiogram, for the moment, is that the depression of the bone curve which one notes at frequencies above 500 cycles, is an artifact in the sense that the normal state of the patient's inner ear is not revealed with full accuracy Failure to consider this artifact when interpreting the audiogram would lead to the erroneous conclusion that the patient possessed a mild sensori-neural involvement Conversely, awareness that this general pattern of mechanical distortion in the bone curve is typical of stapes fixation increases the diagnostic value of the audiometric record

As one would expect, the mechanically produced modification in bone conduction response consequent to stapes fixation varies from patient to patient At least in most cases, however, these variations are not so great that they obscure the general pattern of shift characterizing stapes fixation Most typically, the mechanical shift in the bone conduction curve induced by stapes fixation is of the magnitude and of the shape represented by the shaded area in Fig 1 That is, an otosclerotic patient with normal cochlear function, which would be revealed by a bone conduction audiogram at normal if it were not for the mechanical shift in responsiveness, will most typically yield a notch-like depression of the bone curve which follows the lower boundary of the shaded area in the figure The audiogram shown in Fig 1 did not conform perfectly to this course, but the deviation did not obscure the basic pattern characteristically induced by stapes fixation

Such a notched depression in the bone curve is less obvious to the eye when secondary nerve degeneration is combined with stapes fixation, but it is nonetheless present A typical audiometric record illustrating this situation is shown in Fig 2 The position of the bone conduction curve is shifted and given a downward tilt toward the right by the senori-neural loss which is present in this case If this sensori neural condition were the only impairment present, there would be a smooth progressive drop in acuity with increase in stimulus frequency, however, the smoothness of this progression is obscured by the mechanical distortion in the bone curve which stapes fixation caused Stated conversely, the trade-mark of stapes fixation is to be found in this record, if the clinician wishes to seek it The break which occurs in the bone conduction curve at 2000 c p s is the preliminary clue to mechanical distortion in the curve Confirmation is



AUDIOMETRIC RECORD

Name Miss. M.B. Date 1-19-49

Audiometer Test By J C Audiometer Used A

Fig 1 Hearing levels for the left ear of a 17-year-old girl having clinical otosclerosis without secondary nerve involvement Stippled area indicates usual magnitude of change in bone thresholds induced mechanically by stapes fixation

achieved by subtracting the idealized mechanical notch from the bone curve The residue thus obtained reveals graphically the so-called cochlear reserve, that is, the configuration of sensori-neural acuity which the patient has retained In the present instance, this residue is characterized by the smooth progression in loss for higher frequencies mentioned previously

VI

Many other conductive lesions produce shifts in the bone conduction audiogram Here, physical similarity among lesions, regardless of etiological classification, will determine a particular audiometric configuration For example, permanent damages resulting from otitis media can not all show the same pattern of mechanical artifact in the bone curve simply because they do not all produce equivalent damage in the middle ear mechanism, moreover, until clinicians learn to classify each conductive lesion on the basis of distinctions in the mechanical damage which characterize it, they will be limited in the precision with which they can differentiate among meaningful artifacts in the bone conduction curve

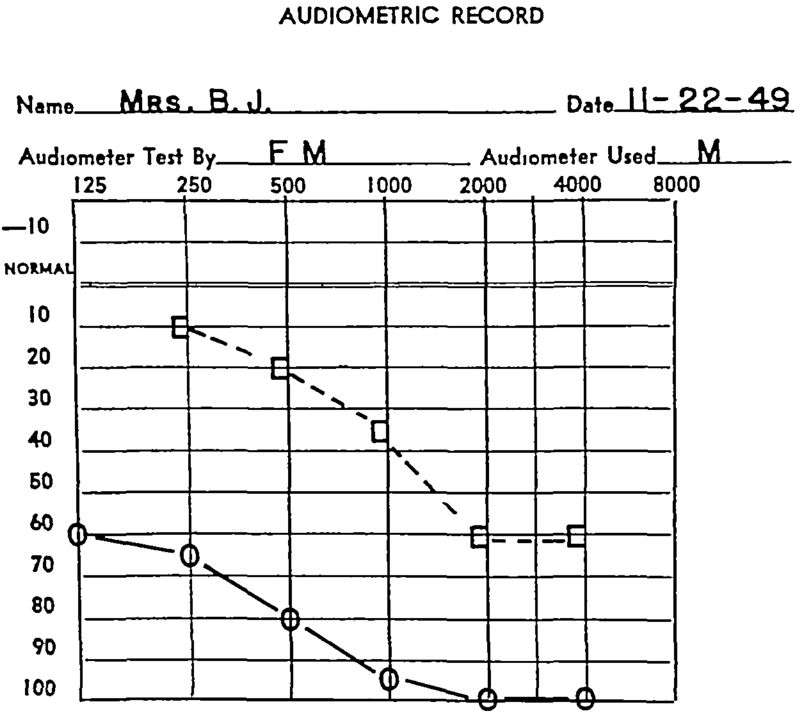


Fig 2 Hearing levels for the right ear of a 40-year-old woman having complete stapes fixation due to clinical otosclerosis plus secondary nerve degeneration

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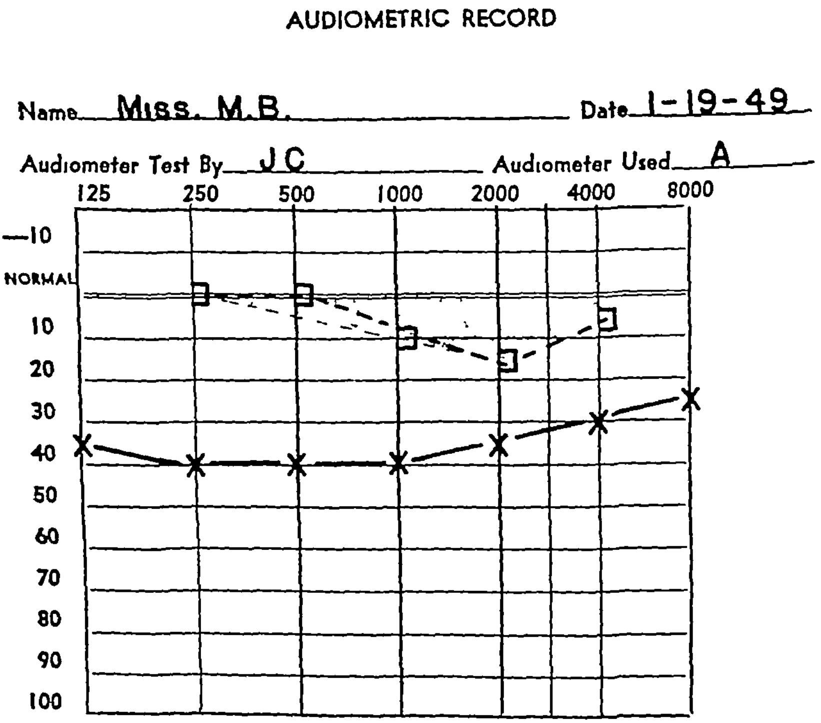
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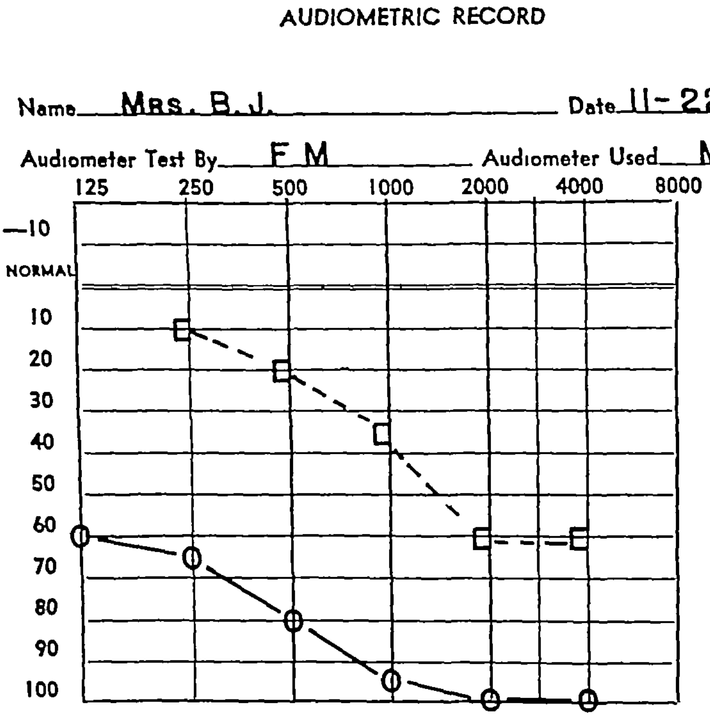
AUDIOMETRIC RECORD

Name Mrs. B. J. Date 11-22-49

Audiometer Test By F M Audiometer Used M

Fig. 2. Hearing levels for the right ear of a 40-year-old woman having complete stapes fixation due to clinical otosclerosis plus secondary nerve degeneration.

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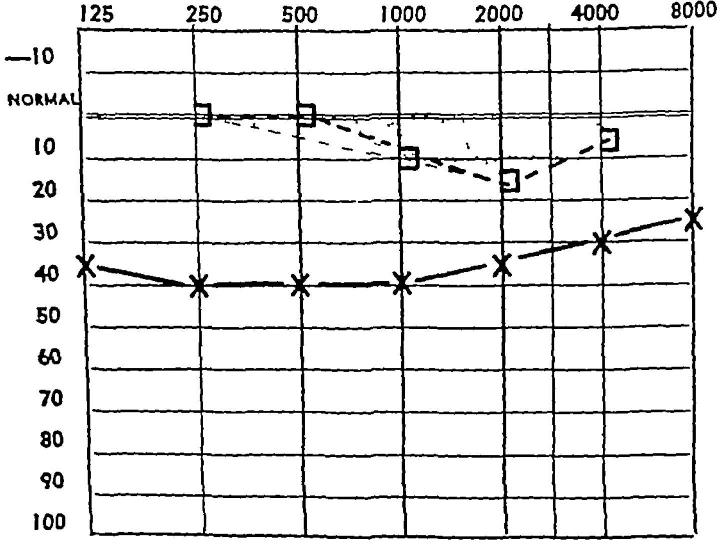


Fig 1 Hearing levels for the left ear of a 17-year-old girl having clinical otosclerosis without secondary nerve involvement Stippled area indicates usual magnitude of change in bone thresholds induced mechanically by stapes fixation

achieved by subtracting the idealized mechanical notch from the bone curve The residue thus obtained reveals graphically the so-called cochlear reserve, that is, the configuration of sensori-neural acuity which the patient has retained In the present instance, this residue is characterized by the smooth progression in loss for higher frequencies mentioned previously chanically Specifically, the case reported in Fig 3 probably did not possess either cochlear hyperacuity for low frequencies or sensori-neural deficiency for high frequencies One reason for arriving at this conclusion is the fact that the patient did not show a high frequency drop by air conduction comparable to the drop by bone This patient's air conduction audiogram, in other words, has a configuration which bespeaks a conductive lesion without appreciable sensori-neural involvement There is a second reason for expressing belief that the pattern of bone conduction response under consideration is mechanically induced Many cases showing this pattern reveal sudden modification in the pattern of the bone curve as soon as the mechanical status of the middle ear is changed One example which comes to mind is a case wherein the bone conduction curve reverted essentially to normal when the patient's perforated ear drum was closed with a paper patch

It is likely that clinicians have often mistakenly interpreted minor decreases in bone efficiency at higher frequencies as evidence of mild sensori-neural involvement Such a sensori-neural involvement is properly assignable only if the air conduction curve incorporates a break in its course that also indicates decrease in acuity for high frequencies When concomitant depression of the air conduction curve is not found, a minor depression in the bone conduction curve should be presumed to be evidence of mechanical modification in the conductive mechanism A similar interpretation is assignable to minor elevations in the bone curve

One must reiterate that it is not currently possible to state the specific nature of the mechanical changes underlying a particular pattern of shift in bone responsiveness Bone conduction audiometry will have increased diagnostic usefulness when research reveals the relationships which are involved The first step is to develop sufficient confidence in the existence of such relations so that they are sought out systematically and their meaning is mastered, moreover, the clinician must remember that, if the patient has lesion or pathology in the middle ear or the external ear, the exact picture of cochlear sensitivity is seldom revealed by the bone conduction

Certain patterns are nonetheless emerging It is possible to illustrate in general terms the value which the clinician can gain from further knowledge of the subtle clues that reside in a good bone conduction audiogram

As one example, consider Fig 3 Again, the results for only one ear are reported The diagnosis in this case was

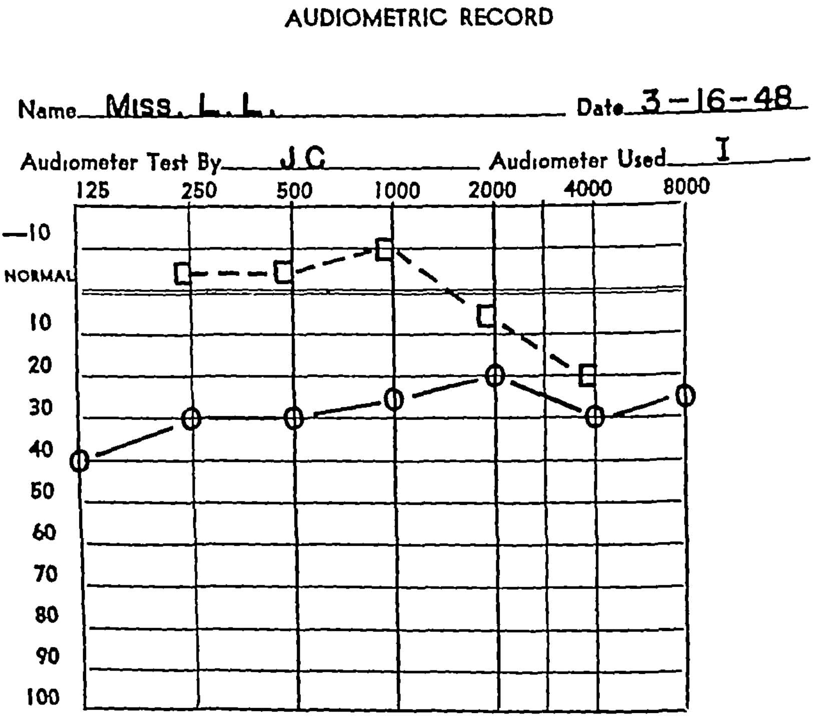


Fig 3 Hearing levels for the right ear of a 13-year-old girl having chronic suppurative otitis media

conductive hearing loss due to chronic suppurative otitis media The important thing is that the responses by bone conduction show a pattern frequently observed when there is disease in the middle ear This pattern, which was described years ago by Lierle and Reger,[15] is characterized at low frequencies by better than normal responsiveness to bone stimuli, and by reduced responsiveness at high frequencies In many instances the entire configuration is probably induced me-dismissed The alternative, an increase in stiffness, is credible when one remembers that the encroaching spicules of otosclerotic bone impose a reduction in the freedom of stapedial movement In a technical sense, the elasticity of the ossicular system is sharply increased at the oval window by this encroachment, moreover, this effect will continue to be the

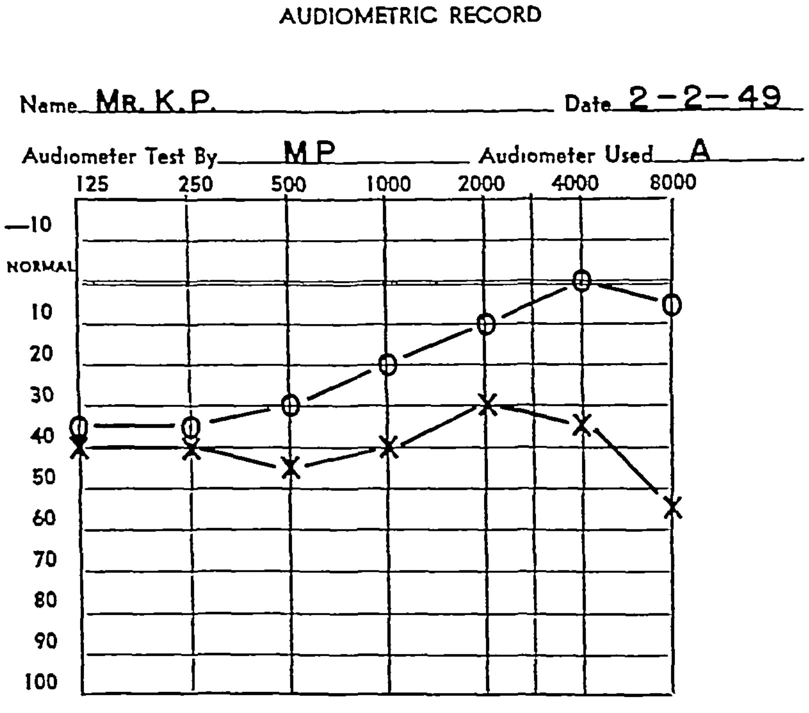


Fig 4 Hearing levels for air conduction exhibited by a 51-year-old man having clinical otosclerosis without secondary nerve degeneration. The right ear with incomplete stapes fixation reveals loss at low frequencies suggestive of stiffness" increase The left ear with complete stapes fixation shows an additional loss at the high frequencies suggestive of mass increase

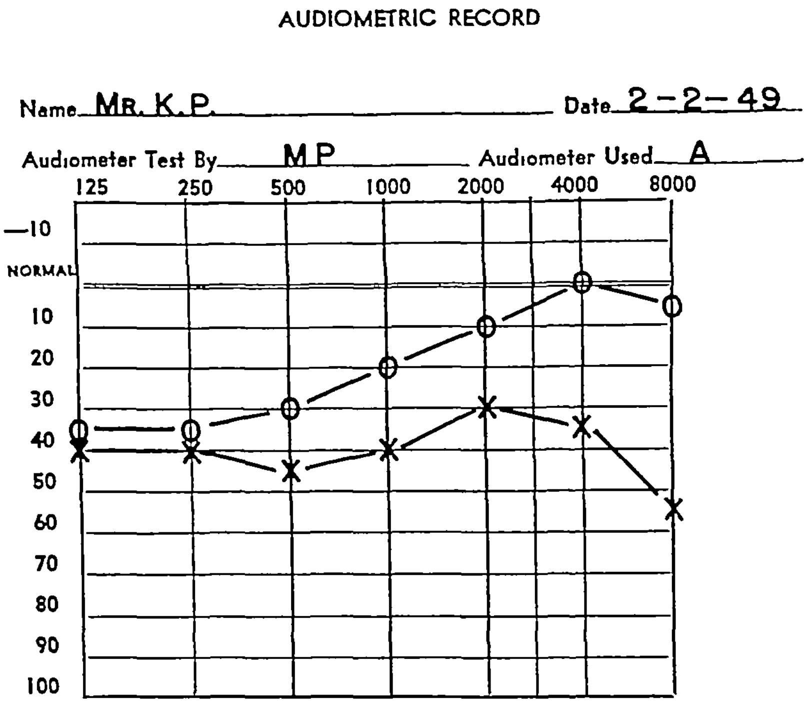
main one as long as some stapedial motility remains The mechanical state must change radically when fixation becomes complete The stapedial footplate must now be so firmly locked within the oval window that the stapes is loaded, at least to some degree, by the mass of the skull This increased mass should reduce the capacity of the system to transmit high frequencies One notes, in Fig 4, that the added im-audiogram True, the general level of cochlear sensitivity may be estimated from this audiogram, but the details of apparent responsiveness will often be distorted by mechanical influences The clinician must make allowances for these influences when estimating the sensori-neural efficiency of a patient with a conductive involvement

VII

Much attention has been given in recent years to the concept that anticipable shifts in air conduction acuity are induced by changes in the mechanical impedance of the auditory system The writings of Metz,[16] Johansen,[10] and Campbell[2] are sufficiently well known so that they need not be reviewed here

The important idea is that the clinician can find value in these concepts when he is interpreting conductive losses Here the configuration of thresholds for air-borne stimuli may be viewed as a manifestation of specific changes which have taken place in the physical constants of the ear Naturally, the clinician is not going to attempt detailed mathematical analyses of individual case records, however, he can profitably bear in mind the general principles which the physicist has made available to him, and which appear consistent with clinical experience, namely, that increased stiffness or decreased mass reduce sensitivity for low frequencies, whereas the reverse conditions reduce response to high frequencies

Consider, as one example, the case shown in Fig 4 Only the two air conduction audiograms are here reported This patient was diagnosed as having clinical otosclerosis without secondary nerve degeneration The stapes was found to be only partially fixed on the right side, but completely fixed on the left The hearing loss in the right ear is substantial for low frequencies and mild for high frequencies According to the principles mentioned above, such a configuration could be either the result of mass decrease or of stiffness increase Since a substantial decrease in the effective mass of the conductive system is inconsistent with the pathology of otosclerosis, the first of these possibilities may be quickly dismissed The alternative, an increase in stiffness, is credible when one remembers that the encroaching spicules of otosclerotic bone impose a reduction in the freedom of stapedial movement In a technical sense, the elasticity of the ossicular system is sharply increased at the oval window by this encroachment, moreover, this effect will continue to be the



AUDIOMETRIC RECORD

Name MR. K. P. Date 2-2-49

Audiometer Test By MP Audiometer Used A

Fig 4 Hearing levels for air conduction exhibited by a 51-year-old man having clinical otosclerosis without secondary nerve degeneration The right ear with incomplete stapes fixation reveals loss at low frequencies suggestive of stiffness increase The left ear with complete stapes fixation shows an additional loss at the high frequencies suggestive of mass increase

main one as long as some stapedial motility remains The mechanical state must change radically when fixation becomes complete The stapedial footplate must now be so firmly locked within the oval window that the stapes is loaded, at least to some degree, by the mass of the skull This increased mass should reduce the capacity of the system to transmit high frequencies One notes, in Fig 4, that the added impairment exhibited by the left ear, where the stapes was completely fixed, is of this very nature

The foregoing discussion is schematic, but it illustrates the manner in which awareness of physical concepts can enhance the clinician's evaluation of the hearing losses he observes A further illustration, with completely different practical

AUDIOMETRIC RECORD

Name Miss. D.S. Date 7-20-49

Audiometer Test By F M Audiometer Used A

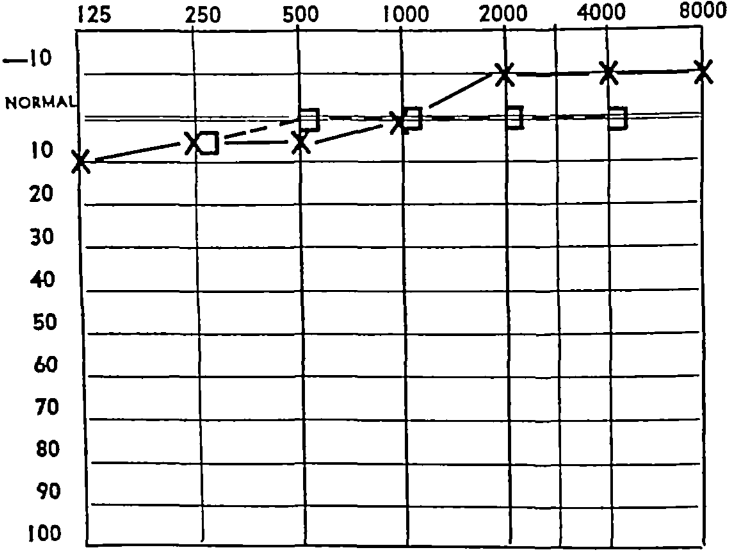


Fig 5 Hearing levels for the normal left ear of a 37-year-old woman having clinical otosclerosis in the right ear The tilt of the air conduction curve in relation to the horizontal curve for bone conduction illustrates earliest audiometric clue to the onset of stapes fixation

implications, is to be found in the audiometric configuration of pre-clinical otosclerosis This configuration was suggested by Campbell[2] Graham[7] found the configuration to be common among teenagers and young adults whose hearing was "normal" and who had close relatives exhibiting otosclerosis The configuration is illustrated in Fig 5 It is characterized by a tilting of the air conduction curve without concomitant shift in the bone conduction response The tilting is sufficient so that an air conduction loss of 10 to 15 db appears at 125 cycles Hearing is near normal at 1000 and 2000 c p s Hyperacuity appears at still higher frequencies This tilting, when interpreted from the standpoint of impedance concepts, leads one to suspect increased stiffness within the conductive system As already pointed out, the mechanical effect of incomplete stapes fixation is to increase the stiffness of the system

The present instance represents a condition where the fixation process is so minor that hearing loss of clinically noticeable magnitude has not yet resulted Nonetheless, the audiogram shows a disturbance in responsiveness to air-borne stimuli which is attributable to minor changes in the conductive mechanism, and which is easily identified by the fact that the bone conduction curve does not reveal any evidence of this disturbance *

The exciting feature of this configuration, from the medical point of view, is that it reveals the presence of otosclerosis early enough so that preventive measures can be applied once they are discovered Thus, the time may come when clinical otosclerosis, as we know it today, will seldom be allowed to develop, because the disease can be discovered very early and can be controlled through medical, dietetic, or other non-surgical means

In summary, as exemplified by the cases just discussed, lesions of the conductive system produce changes in hearing which are consistent with the principles governing mechanical systems The clinician can facilitate his tasks in diagnosis by remaining alert to the manifestations of these principles which appear in the air conduction audiogram [11]

VIII

The problem of differentiating among sensori-neural losses is complicated One task is to segregate cochlear (end-organ) lesions from retro-cochlear (neural) lesions A further task

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*The mechanical effects are so minor at this stage that the notched depression of the bone curve which one expects with clinical otosclerosis has not yet appeared.

is to locate the site of damage accurately, to designate definitively the structures involved, and to describe specifically the pathology which is, or has been responsible for the hearing difficulty. Of course, much needs to be learned before full diagnostic precision will become possible here.

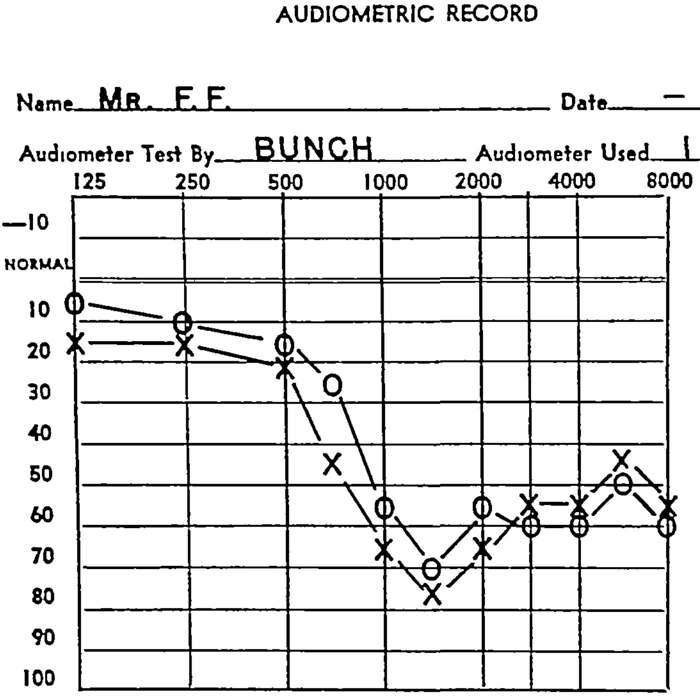
Fortunately, a wide variety of auditory tests directed toward this goal have been developed or adapted in recent years. Many of these tests have been of the supra-threshold variety, *i.e.*, loudness balance techniques, methods for measuring DLs for intensity change, tests of speech discrimination in quiet and in noise, and the delayed side-tone procedure. It is still too soon to specify the ultimate usefulness of all these techniques; however, their clinical applications are rapidly becoming clarified in consequence of extensive research from different parts of the world. The diagnostician's efficiency has already been enhanced significantly, and future research will bring him added insight.

The emphasis on new tests has diverted attention from the contribution which conventional threshold audiometry can make to differential diagnosis among sensori-neural lesions. There is no reason to believe that the limits in interpretation of the audiogram have been reached; in fact, critical study of audiometric configurations suggests subdivisions in diagnostic categories which the clinician does not currently consider. Clinicians, (and theorists) can profitably re-examine the significance of threshold audiometry.

IX

It would be premature to attempt a systematic description of the array of clues to differential diagnosis which are available through plotting thresholds for pure tones. One can, however, illustrate the existence of such clues by discussing examples involving sensori-neural losses. These examples consist of audiometric pecularities which are easily recognized, but which still await full interpretation.

One example is the configuration of sensori-neural loss wherein acuity for low frequencies is near normal, and wherein there is sharp transition to a plateau of high frequency loss at about 60 db This type of impairment is relatively common, and its existence can be demonstrated either from contemporary clinical records or from the literature Figs 6 and 7 are samples of this configuration taken from Bunch's original records, which are preserved at Northwestern University Fig 8 plots a similar impairment, as found in a

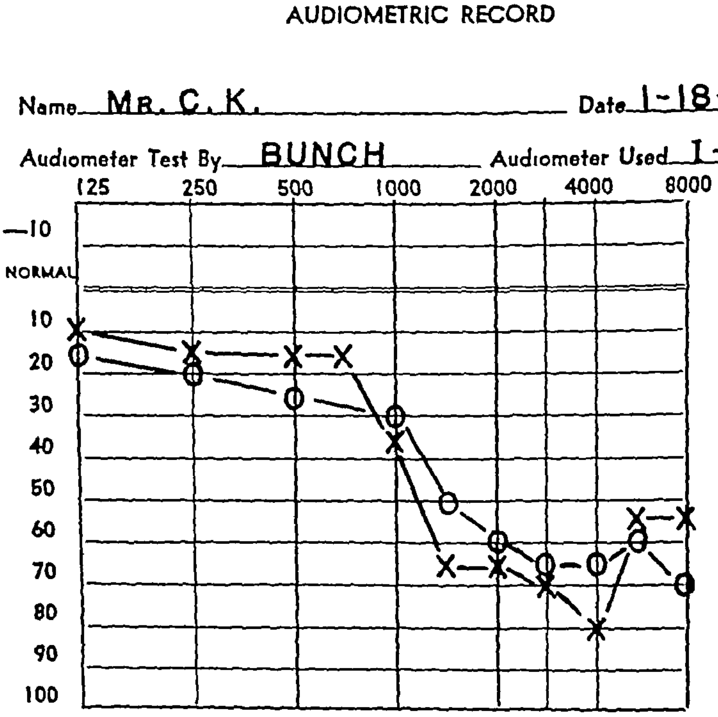

AUDIOMETRIC RECORD

Name MR. E.F. Date –

Audiometer Test By BUNCH Audiometer Used I A

Fig 6 Hearing levels for air conduction exhibited by 44-year-old man employed as a riveter

case tested at Northwestern in 1957 These three exemplify an audiometric feature which is quite common, even though it does not repeat itself with perfect consistency from one patient to the next The existence of a distinctive type of lesion can be postulated from the fact that so many high frequency losses plateau at approximately the 60 db level of loss This lesion must be of such nature that it does not interfere with acuity for low tones, nor with response to intense sounds at high frequencies One can not help but speculate that this lesion may be geographically restricted, so that neural representation from the outer hair-cells within the basal region of the cochlear spiral is lost, while excitation from the inner hair-cells within the same region continues to have central representation, as does excitation from the more apically located hair-cells of both varieties Minor differences in the extent, the severity, and the purity of the lesion could account for the clinical variations observed in hearing losses of this general type



AUDIOMETRIC RECORD

Name Mr. C. K.

Date 1-18-35

Audiometer Test By BUNCH

Audiometer Used 1-A

Fig 7 Hearing levels for air conduction exhibited by a 25-year-old man with sensori-neural involvement of unspecified etiology

The foregoing speculation does not require the presumption that the outer hair-cells have been destroyed, although such a situation is one possibility An equally tenable alternative is the possibility that the innervation from these hair-cells to the central nervous system is defective There may, moreover, be other alternatives, and subsequent study may reveal that several types of lesion produce the audiometric configuration under discussion

The idea being stressed at the moment is that this unique audiometric configuration must result from patterns of lesion which are distinctive It is convenient, since the external

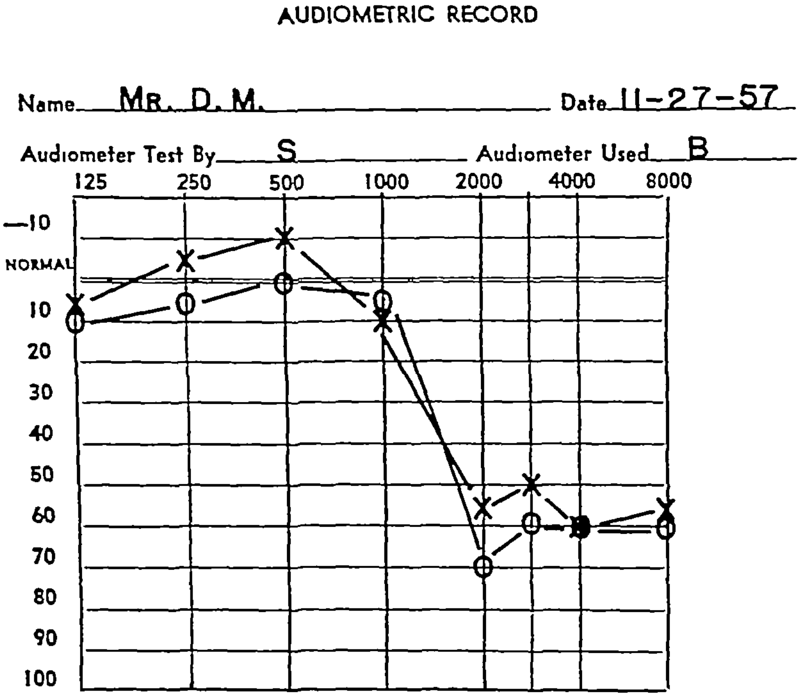


Fig 8 Hearing levels for air conduction exhibited by a 59-year-old woman with bilateral sensori-neural involvement of unknown etiology

hair-cells are thought to mediate response to weak stimuli and are more susceptible to damage from intense stimulation,[6] to evoke the speculations advanced in the preceding paragraph, however, these speculations are not essential in the present discussion They merely illustrate the kind of thinking which study of threshold audiograms excites The fundamental premise, which neither clinician nor theorist dare ignore, is that every hearing loss is the product of a specific set of lesions These lesions determine the nature of the audiometric configuration which the patient exhibits The fact that diverse patterns of pure tone loss are encountered indicates that auditory lesions differ not only in extent but also in kind One way in which clinical audiology can participate in classifying the conditions involved is by renewing its interests in the details of audiometric configuration One practical benefit will be that the diagnostic usefulness of conventional audiometry will increase

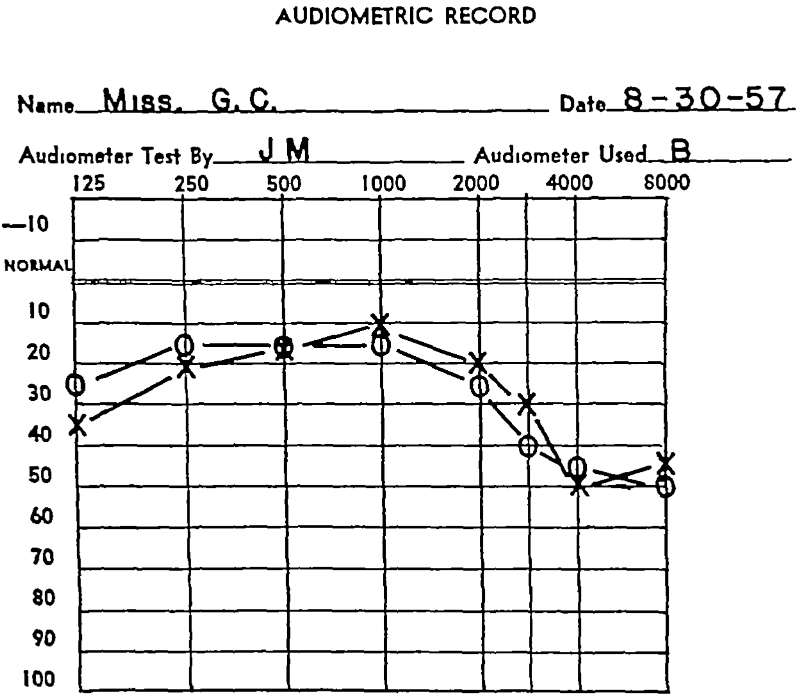
X

Consider two additional illustrations of the diversity of information which the pure tone audiogram can contain Both illustrations involve peculiarities of auditory function frequently found in conjunction with presbycusis

One of these peculiarities is exemplified in Fig 9 Note that here the loss exhibited at 125 c p s is greater than at 250 c p s This configuration has been observed as a group trend in various studies where general populations of elderly people have been sampled[4, 12] It also appears as a clearly identifiable feature in the audiograms of many clinical cases, who sometimes yield thresholds 15 db poorer at 125 c p s than at 250 c p s

Such findings are baffling if one attempts to account for them on the basis of peripheral lesions in the sensori-neural mechanism of the ear In other words, the peripheral degeneration of hair cells and spiral ganglion cells, which has been observed to characterize presbycusis,[18] cannot account for the increased loss at 125 c p s This degeneration affects the sensori-neural structures serving the basal region of the cochlea It consequently disturbs acuity for higher frequencies Any effect it may have at 125 c p s should not be more severe than the effect at 250 c p s , moreover, these two latter frequencies are within the range which cochlear agitation is diffuse and where, stated in general terms, the same structures will be stimulated by both stimuli Thus, since volleys of neural impulses are the intermediaries to perception of low frequency tones, the distinction within the auditory system between a tone of 125 c.p.s. and one of 250 c.p.s. is a difference in the rate at which the volleys are triggered.

It seems reasonable to conclude that many elderly persons who retain equivalent peripheral sensitivity at these two frequencies require a greater comparative intensity in order for stimulus to be perceived when the volley rate is 125 per second, than when it is 250 per second.* In such event, the extra impairment in acuity found at 125 c.p.s. must depend upon a disturbance of function within the central nervous



AUDIOMETRIC RECORD

Name Miss. G. C. Date 8-30-57

Audiometer Test By J M Audiometer Used B

Fig. 9. Hearing levels for air conduction exhibited by an 80-year-old woman having presbycusis. This chart exemplifies cases with greater loss at 125 c.p.s. than at 250 c.p.s.

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*The alternative would be that the ageing of structures within the inner ear changes the mechanical constants of the auditory system in such manner that its responsiveness to very low frequencies is differentially impaired. This possibility seems a less likely source for the phenomenon under discussion.

system It would be foolhardy to speculate regarding the site or the nature of such malfunction, however, because such a disturbance could disrupt various facets of auditory behavior[1,17] and hence complicate a patient's problem, the clinician must be alert to the potentiality that it may be present in a particular case Proper attention to the audiometric configuration can warn the clinician of this potentiality

A second peculiarity in the auditory response of some elderly patients is an abnormally great loss by bone conduction at 500 c p s This phenomenon was identified by Bernero, who noted it in the records of the Hearing Clinics at Northwestern University The audiometric technique employed in these Clinics is one wherein masking is not used routinely while testing bone conduction Masking is introduced only when the patient states that his auditory experience is not localized to the ear under test This fact is mentioned because, as described below, it appears to be an important condition in evoking the Bernero phenomenon

A typical example of the phenomenon is reproduced in Fig 10, which gives results for only one ear The agreement between air and bone thresholds is good except at 500 c p s Tradition would lead one to discount the difference at 500 c p s as being due to testing error, however, this particular discrepancy is observed so repeatedly that it can not be dismissed in a cavalier fashion, and one can not ignore evidence such as the observation by Ciocco,[5] reported in 1934, that elderly persons have disproportionately reduced acuity by bone conduction when tested with the 512 c p s tuning fork, therefore, the clinician is justified in suspecting that he is encountering the Bernero phenomenon when the patient is elderly, when the bone conduction threshold of 500 c p s is 10 to 15 db poorer than the air conduction threshold, and when the remainder of the audiogram shows the close correspondence between measures to be expected in sensori-neural loss

The Bernero phenomenon cannot be explained by conventional principles of audiometric interpretation These principles specify that loss is less for bone than for air when the impairment is of the conductive variety, whereas the two losses are equal when the lesion is a sensori-neural one Only in rare instances of skull anomaly, such as Guild has described,[8] could gross mechanical factors account for excessive loss by bone, and here the effect should not be limited to one frequency, thus, only two alternatives remain

AUDIOMETRIC RECORD

Name Mr. C.P. Date 10-10-48

Audiometer Test By C H Audiometer Used I

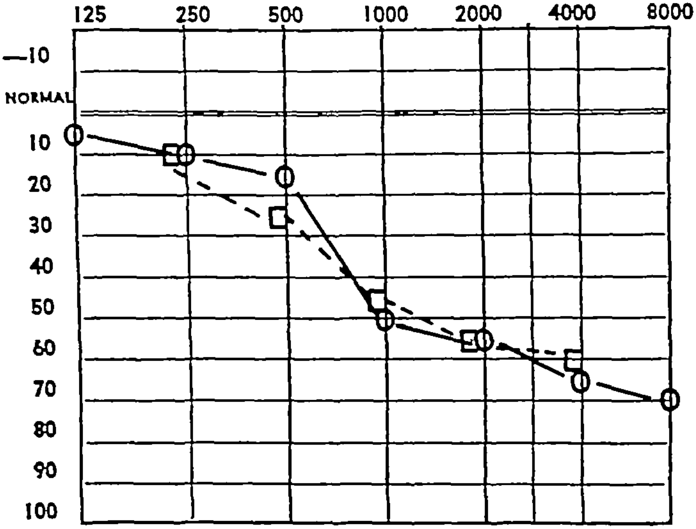

Fig 10 Hearing levels for the right ear of a 71-year-old man having presbycusis This chart illustrates cases with noticeably greater loss at 500 c.p s by bone conduction than by air conduction

One possibility is that ageing has modified the mechanical constants within the inner ear in such a manner that a differential reduction in the responsiveness of the auditory system of skull-borne vibration at 500 c p s has been produced This possibility seems relatively unlikely, even though some writers have postulated that ageing sometimes produces a conductive loss within the inner ear in consequence of the physical changes that occur there system. It would be foolhardy to speculate regarding the site or the nature of such malfunction, however, because such a disturbance could disrupt various facets of auditory behavior[1,17] and hence complicate a patient's problem, the clinician must be alert to the potentiality that it may be present in a particular case. Proper attention to the audiometric configuration can warn the clinician of this potentiality.

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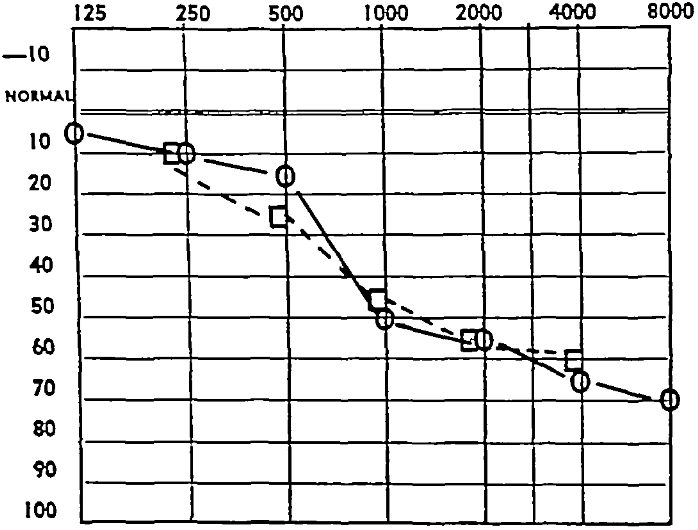
AUDIOMETRIC RECORD

Name MR. C.P. Date 10-10-48

Audiometer Test By C H Audiometer Used I



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The alternate possibility is that the Bernero phenomenon appears whenever the bone conduction stimulus is more difficult to perceive than is the air conduction stimulus. This alternative presumes that peripheral sensitivity is the same for the two modalities, but that a functional peculiarity is operative which makes conscious recognition of the bone conduction stimulus at 500 c.p.s. difficult. A potential mechanism comes to mind quickly. One need merely remember three facts: *1* in presbycusis the two ears usually exhibit bilateral symmetry of loss; *2* when such bilateral symmetry exists the air conduction stimulus activates only the ear under test, so that monaural excitation occurs at threshold; *3* the bone conduction stimulus reaches both cochleas. Such a stimulus should excite both ears if they are similar in sensitivity and neither is masked. True, the levels of stimulation will seldom be identical, and the experience of hearing will ordinarily localize to one ear or the other.

Bilateral excitation by bone goes unnoticed in most clinical circumstances; however, it may be a critical consideration when perceptual abilities are reduced, albeit subtly, by age. Stated differently, the foregoing considerations lead one to interpret the Bernero phenomenon as indicating a condition wherein the cortical differentiation of two trains of neural impulses is more difficult when the impulse rate is 500 per second, than is the differentiation of a single train; and one must presume, since the phenomenon is restricted to 500 c.p.s., that this disadvantage in bilateral hearing is not apparent when the stimulus frequency is either markedly lower or markedly higher in frequency. The reasons for such a circumscribed disturbance in perception are obscure, but its existence cannot be ignored. Thus, it would seem that the Bernero phenomenon is a clue to a central perceptual disturbance. As such, it is a second audiometric aid to the identification of those elderly persons whose hearing difficulties are not exclusively of peripheral origin.

XI

A point worthy of re-emphasis is the fact that understanding of auditory abnormalities is currently imperfect. Both the clinician and the theorist must remember that there are aberrations in hearing function which the usual testing procedures do not reveal The diagnostic significance of such aberrations will emerge as the aberrations become known and understood One result will be further insight into the meanings which can be assigned to results of conventional audiometry

Consider the phenomenon of abnormal auditory adaptation as it is revealed through the tone decay test[3] The procedure is to present a sustained pure tone at threshold for a full minute unless the patient signals that the tone has become inaudible In the latter event, the intensity is increased 5 db , and the timing is started anew This routine is repeated until an intensity is found at which the tone remains audible for 60 seconds The exploration is then complete at this frequency, and a new exploration may be started at another frequency

Results for the tone decay tests are classifiable into three general categories Cases with conductive loss, and some with sensori-neural impairments, do not reveal auditory adaptation at threshold Other cases of sensori-neural loss exhibit moderate adaptation for high frequency tones, *i e* , up to 25 db drift in the level at which the tone remains audible Adaptation for low frequencies is rare Finally, occasional instances occur in which adaptation is so extreme that the tone is heard for a full minute only at great intensities, or else not at all This extreme type of adaptation has been encountered both in cases where there is hearing loss in the ordinary sense, and in instances where standard audiometry yields normal thresholds Such findings indicate unusual auditory disturbances Tentatively, it appeared that adaptation as extreme as this is the result of a neural lesion,[18 10] while moderate adaptation probably has its origin in the cochlea[9] It would seem, moreover, that not all types of disturbance in either locus produce abnormal adaptation at threshold, since many sensori-neural losses do not exhibit any tone decay at threshold This matter will have to be clarified by further research

The foregoing discussion not only illustrates the fact that abnormalities in auditory function are complicated and, hence, emphasizes the need to classify clinical sub-types more adequately It also calls attention to phenomena which must be kept in mind by the clinician as he interprets conventional threshold tests He should, for example, become immediately suspicious that a problem of abnormal adaptation may exist whenever he encounters a subject whose threshold level seems to vary excessively from moment to moment Stated differently, the fact that a patient's audiometric responses are highly unreliable may be a clue to unique features in his hearing loss which can be quantified if explored with an appropriate additional test

XII

In summary, the pure tone audiogram can be of great help in the differential diagnosis of hearing losses The configuration of the air conduction curve often suggests etiology, and in cases of conductive loss, the nature of the mechanical disturbance In addition, air-borne relationships distinguish conductive from sensori-neural involvements Minor variations in the bone conduction curve are characteristic of different conductive lesions Finally, threshold audiograms contain much information which awaits full codification and which, when so codified, will contribute to a new level of precision in differential diagnosis among hearing losses

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DR. HIRSH We have time for a question

DR. MOE BERGMAN (New York, N Y) I would like to express my own gratification as I am sure the whole group does Professor Carhart is continually urging us to go back and look at our audiograms very carefully

I would like to ask a question on that last slide, and that is on that very provocative case of tone decay I wonder, again, whether there is a relationship between the recruitment and the loss of loudness in the better ear as against the growth of loudness in the worse ear. Is the recruitment due to a growth of loudness in the poor ear, therefore, giving us equal loudness, or because of the decay in the better ear?

DR. CARHART There might be just the reverse. The better ear has such a low level of loudness that the match is made close to threshold even though there is no recruitment, in the conventional sense, in the better ear.

These questions which you raise are very exciting and represent part of the speculation which ought to be done I can simply report to you facts In elderly people, at least, I am convinced that this phenomenon of poor hearing, 125 and 250, is sufficiently frequent so that it cannot be accounted for on mechanical ground or some immediately explainable ground which we might think of, since we do not find it simultaneously in the same clinical run, so to speak, on cases that do not fall in this category

DR HIRSH The first question had to do with physical factors that make the measurement of 125 unreliable

DR. CARHART I thought I answered that simply by stating that this is an observation made under clinical circumstances where other types of cases did not seem to show unreliable responses to 125

DR TAUNO PALVA, (Turku, Finland) I should like to comment on certain aspects of Dr Carhart's paper, although I am supposed to discuss some of these phenomena in my own presentation to be given later

The last slide shown by Dr Carhart described a very large stimulatory adaptation loss during only some thirty or forty decibels of stimulation What is even more remarkable is that there was similar fatigue in the healthy ear as in the deaf ear If the result is real, I think it is an extreme variant I have made a continuous threshold recording during four minutes stimulation in over two hundred cases, representing mostly recording perceptive type of lesions, but I have never seen as severe per-stimulatory fatigue as described by Dr Carhart

In my experience the threshold sensitivity loss does not generally exceed 30 to 40 db, and it does not occur in more than 15 to 20 per cent of the patients with perceptive lesions

My second point concerns the slight loss of bone conduction observed by Dr Carhart at higher frequencies in certain cases with chronic ears Supposing that some of these ears had perforations in the tympanic membrane with dry cavity, I should like to know whether bone conduction measurements were also made when the tympanic perforation was closed, for instance, with a cigarette paper patch The possible difference in the open and closed perforation could tell us whether the slight bone conduction loss was due only to the altered conductive ability of the tympanic membrane or whether there were also changes in the window nucleus that could be responsible for a covered bone conduction

DR. CARHART I would not wish to attempt to state what particular kind of mechanical factor might be responsible for the type of thing I was talking about in the bone conduction test

I will comment briefly on the first point you made, Dr Palva This particular kind of a test is a sort of first inventory, of course, and this particular case, while it is extremely unusual, and I suppose, for that reason makes a beautiful demonstration, is nonetheless one whose validity, whose clinical reality I cannot doubt, because the person who did this happened to be a Danish physician who was working with us at the time, and who did not believe the results of the test the first time and, therefore, returned and repeated the test and got the same results the second time

DR. HIRSH Our discussion of audiometry has begun with the role of the audiogram, which is, as Dr Carhart told you, useful, and in addition, the pure tone adaptation test which Dr Carhart has implied will be useful in the future

Let us return now to a consideration of a very important set of problems surrounding the syndrome known as Ménière's disease

MENIERE'S DISEASE

THEODORE E WALSH,

St Louis, Mo

I would like to bring up one point first about audiology in the diagnosis of Ménière's disease I find the audiologist is quite a help, but I would emphasize that the diagnosis is made by clinical observation. I am not being facetious; I just want to emphasize the point that it is a careful history of the case and a careful observation of the patient by which the diagnosis of Ménière's disease is made. The audiologic findings simply confirm the diagnosis.

Let us first take up the symptoms of Ménière's disease. Patients with this disease usually seek help because they are dizzy. It is usually not difficult to determine whether this dizziness is truly vestibular in origin or whether the so-called dizziness is not related in any way to the labyrinth. Although the main complaint is directed at the vestibular symptoms, it is really cochlear dysfunction which is responsible for the condition. I emphasize the point that I believe Ménière's disease is primarily a cochlear disease.

In taking a careful history of patients one can usually determine that they noticed some loss of hearing before they ever had their dizzy spells. Patients seeking help for Menière's disease not only complain of dizziness but they also notice deafness, and they complain bitterly of tinnitus.

Now to discuss these symptoms individually, first, tinnitus. The most common description given of this tinnitus is that it sounds exactly like the noise heard when listening into a sea-shell, or the sound of the roar of the surf breaking on the seashore. Those individuals who have never been fortunate enough to listen into a seashell or hear the surf, will tell you that the sound they hear in their ear resembles the roar of a high wind in a forest or sometimes the sort of sound one hears when listening close to a telephone pole in a high wind. The patients also complain of a full feeling in the head which cannot be described in any other way except that it is a full feeling. The hearing fluctuates. At times these patients say they hear "perfectly" and at other times "nothing at all," but, on careful questioning about the hearing, most of them say they can hear but they do not understand. This ability to hear and not understand is easily demonstrated when talking to these people. One seldom has to raise one's voice in talking to a patient with Ménière's disease even if he is in a period of "hearing nothing at all," but one must talk very slowly and very distinctly.

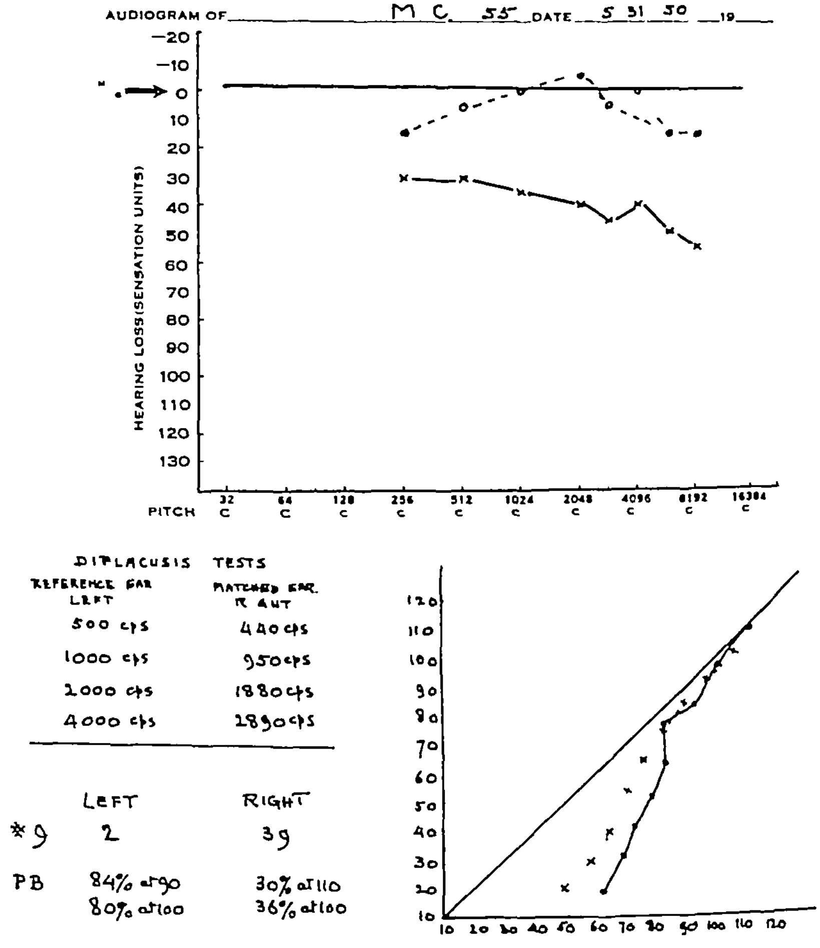
Another complaint, which is more noticeable in musical people, is that of a different sensation of sound in the two ears, diplacusis This is very common If the patient is not musical he will tell you that sounds are different in the two ears, and he describes the sound in the worse ear as fuzzy In the office we test for this diplacusis by the use of tuning forks, and I would emphasize that it is important to test with all forks throughout the whole range, because diplacusis may not be present at every tone Frequently they notice no difference, for example, with a 500 cycle fork whereas when one uses the 4000 cycle fork it sounds different in the two ears and vice versa

The vestibular tests are on the whole not much help in making a diagnosis of Menière's disease We may find a normal response in the two labyrinths, we may find a canal paresis in the affected ear, or we may find a directional preponderance, first to the affected side and later to the normal side It depends a good deal on how long the condition has been present as to what vestibular findings will be Now I would like to show some slides that illustrate these various points, the important points in the audiology of Ménière's disease

Fig 1—In this you see the pure tone audiograms of the two ears, one ear being perfectly normal and the other one not This is not a very common pure tone curve in early Ménière's disease As a rule the pure tone audiogram shows a greater loss in the low tones and almost no loss in the high tones in the early cases, and later the curve flattens and there is an equal loss throughout the scale, still later more and more of the high tones are lost as well as the low, so that one has a down-sloping curve

Diplacusis is well shown in this individual, and you notice that the 500 cycle tone is matched fairly closely, but at 4000 cycles he matches it with 2890 I always feel sorry for people with that sort of diplacusis It must be incredibly difficult to live with, if one is musical

One of the points I mentioned, in our office examination, that these individuals had not much loss for speech at thresh-



DIPLACUSIS TESTS

REFERENCE EAR LEFT	MATCHED EAR. R AUT
500 cps	440 cps
1000 cps	950 cps
2000 cps	1880 cps
4000 cps	2890 cps

	LEFT	RIGHT
*9	2	39
PB	84% at 90 80% at 100	30% at 110 36% at 100

Fig 1

old but considerable difficulty with discrimination, and this is shown here I would like to emphasize this point, because in going through a considerable number of these cases I found in no instance was the discrimination score better than 50 per cent, whereas the threshold was seldom more than a 40 decibel loss

Figure 2 illustrates much the same thing In this individual the fluctuation in hearing is well shown I would like to emphasize this fluctuation in hearing because it makes it very difficult for us, as clinicians, to determine whether any therapy we use is really doing any good unless we can follow the patient over a considerable period of time This particular individual was under treatment during the time between December, 1950, and February, 1951, and it will be seen that his hearing was different on three different occasions Here, in January, 1951, he has a normal hearing for speech, whereas in February, in spite of therapy, he drops to a 40 per cent discrimination score and a 29 decibel threshold loss

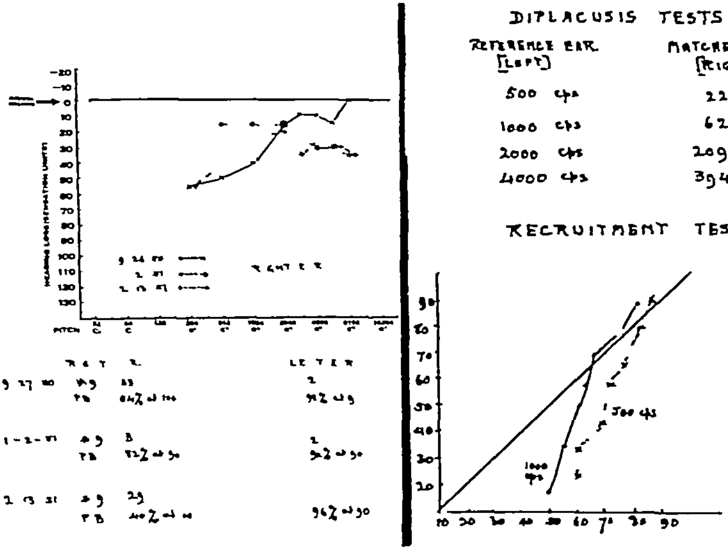


Fig 2

Figure 2 also shows the same patient's recruitment and the diplacusis In this instance, he had a considerable difference in the hearing for low tones rather than in the high

Now the fluctuation in hearing, I think, is important It is very important to start therapy in these individuals when the hearing is fluctuating, because it seems to me that that is when there is a chance of saving some hearing and really rehabilitating these individuals It is true that the treatment of Ménière's disease is directed first toward the relief of the unpleasant and dangerous vertigo Unfortunately, that is

																	Speech			
	Right								Left								Right		Left	
Date	256	512	1024	2048	2896	4096	5792	8192	256	512	1024	2048	2896	4096	5792	8192	T L	Dis	T L	Dis
12/1/55	45	55	65	50	50	60	/	/	25	30	15	10	45	50	65	60	85	6%	16	80%
12/29/55	40	50	60	35	50	65	/	/	30	40	40	25	50	55	60	65				
1/9/56	30	35	35	30	55	65	/	/	45	40	45	20	50	55	65	60	27	32%	29	54%
2/6/56	25	30	25	15	40	65	/	/	30	45	50	30	50	55	65	60	15	64%	43	24%
2/20/56	--											---	--	--	--		16	72%	30	50%
3/5/56	25	30	20	15	45	65	/	/	20	5	15	20	50	55	65	60	12	66%	0	80%

The meaning of the abbreviations is as follows T L threshold loss Dis discrimination

Fig 3

where it usually stops As a matter of fact, I don't believe that the relief of vertigo is nearly so difficult as the preservation of hearing That this preservation is possible by treatment I would like to show in Figure 3

This is a man who has a bilateral Ménière's disease You can see that his hearing in both ears is fluctuating considerably but on treatment he has remained at this good level for quite some time

Figure 4 illustrates the same sort of fluctuation This is an old man with presbycusis in one ear and Ménière's disease in the other When we started therapy the hearing in the ear with Menière's disease had only 28 per cent discrimination, but on treatment it went up to 76 per cent, and his threshold also improved When the medication was changed his hearing dropped, but we have been able now to preserve him at a level of some 70 per cent discrimination for several years

To summarize the audiologic findings, the important ones are *1* Fluctuation in the hearing which gradually becomes worse until almost complete deafness results *2* The loss at threshold for speech is not great in comparison with the discrimination loss *3* Early pure tone audiograms show an up-sloping curve and later the curve flattens and finally the high tones are lost *4* Diplacusis is almost always present *5* The tinnitus is described as a roaring sound and there is a full feeling in the ear *6* Finally, the most important point in the differential diagnosis of Ménière's disease is the invariable presence of recruitment that even becomes in some instances hyper-recruitment

DR HIRSH Are there any comments?

UNIDENTIFIED DOCTOR I would like to comment on diplacusis which is observed in many cases In effect, the diplacusis may sometimes make very difficult the evaluation of the other ear, which is very useful for diagnostic purposes, and I should like also to stress that in my opinion it is not always easy to make a pure audiological diagnosis

	Right								Left								Speech			
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2/19/53	0	0	0	15	30	35	25	25	25	20	10	45	50	40	65	45	--	--		
3/25/53	0	0	0	30	45	50	50	55	50	35	45	35	45	50	50	45				
5/5/53	0	0	0	45	55	55	55	60	45	35	30	25	45	45	55	35	11	66%	42	28%
2/9/54	0	0	-5	40	55	55	60	60	20	25	10	15	40	45	55	40	5	60%	16	76%
2/1/55	-5	-5	0	35	50	55	50	55	30	35	35	10	45	45	55	40	8	68%	28	72%
10/18/55								--					---	---	--		6	70%	30	54%
12/13/55			---					---									6	64%	31	56%
2/7/56				--				---									3	70%	27	60%

The meaning of the abbreviations is as follows T L. threshold loss Dis discrimination

Fig 4

of Menière's disease. We have several diseases characterized by vertigo which are not Menière's disease, but are due to some disease of the nerves, for instance, the fact of a patient having vertigo and practically normal hearing. This could be an unusual case of Ménière's disease without impairment of the auditory function, but we could not do without the vestibular examination in all cases of Ménière's disease because it not only informs us about the condition of the vestibular apparatus, but also adds very much to our diagnosis. In effect, if you find a man who has vertigo and normal hearing and you send him to the audiologist who says that he finds a total loss—we are clearly dealing, not with a Menière's disease but with a neuritis of the acoustic nerve, because in Menière's disease it is impossible to have a total loss of function of the vestibular apparatus. On the other hand, we have total loss of hearing or a severe loss of hearing with a fairly normal vestibular nerve. Now, this is generally due to the fact that we are dealing with a cochlear neuritis. In fact, we might rely on some combinations of cochlear and vestibular diagnostic testing. If we have a total loss of hearing and a total loss of vestibular function on one side, we may, likewise, make a diagnosis of neuritis of the VIIIth nerve, and in the history of the patient we never discover any sign of even the slightest vertigo. We are confronted in this case with a tumor of the acoustic nerve. It is my opinion that no diagnosis of Menière's disease should be made unless the vestibular examination and the cochlear examination agree as to their results. The results must go hand in hand, otherwise we are not certain that we are dealing with a Ménière's disease and not with an infection of the head nerves.

DR. VICTOR GOODHILL. I fully agree with Dr. Walsh that tinnitus may be the consideration that he described in Menière's disease, however, I have seen this type of tinnitus in otosclerosis not too rarely, and in other lesions, which prompts me to urge my audiological colleagues here today to give more attention to tinnitus analysis in the overall approach to diseases of the ear. I think we have neglected the symptom of tinnitus, and that can help us a great deal if we set out to get some technique for clinical attention, qualitatively and quantitatively.

COCHLEAR VS RETROCOCHLEAR LESIONS

TAUNO PALVA,
University of Turku,
Turku, Finland

It is a general rule that the major division between hearing disorders of conductive and perceptive type is made on the basis of a pure tone audiogram If bone conduction is normal or clearly better than air conduction, the case is labeled as conductive, if it equals or is poorer than air conduction, the deafness is classified as perceptive The first conclusion always holds true In the latter case, classification is not so simple, therefore I feel that, before discussing the differences in the subgroups of perceptive deafness, it is necessary to say a few words about cases where air conduction approaches or equals bone conduction, though there is a purely conductive deafness

Together with Ojala,[1] I have pointed out that in nearly one-third of the cases with simple acute otitis media, bone conduction is abnormally poor as long as the middle ear has not healed In these cases, however, the diagnosis can be ascertained simply by looking at the tympanic membrane, but diagnosis is no longer so easy in cases of serous or adhesive otitis generally associated with only minor alterations in the tympanic membranes These cases present a typical curve of perceptive component with lowered bone conduction, most severely at the higher end of the scale The reason for this is either serous secretion which fills the window niches and the middle ear, or adhesions and thickened mucous membranes which fix both windows In the absence of inflammation both air and bone conduction instantly return to nearly normal values when the serous fluid is aspirated

Otoscopic examination with Siegle's speculum and aspiration of the middle ear are the most important assets in separating these cases from true perceptive deafness In rare cases even exploration of the middle ear may be necessary to obtain a correct diagnosis and to return good hearing

If it is established that the middle ear is normal, equal air and bone conduction indicate perceptive deafness In the large majority of cases the lesion is localized to the end-organ or to the VIIIth nerve, only a few cases present a more central pathology

Recruitment Testing

In dividing perceptive deafness into these two main subgroups, it has been customary to use the recruitment of loudness as a criterion Fowler's[2] original concept was that this phenomenon occurs in perceptive deafness in general, and is not typical of any more definitely localized lesion Tests of loudness recruitment have enjoyed increasing popularity only since 1948 when Dix, Hallpike and Hood[3] stated that recruitment is pathognomonic of end-organ disease, more specifically of lesions in the hair cells

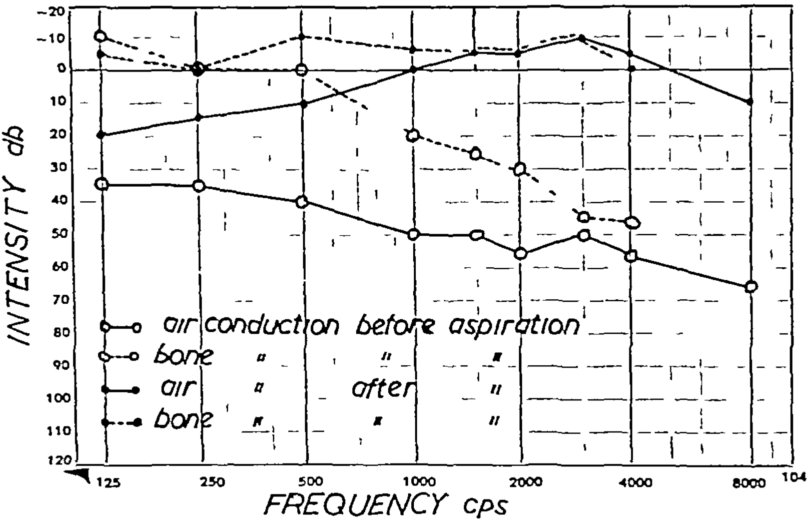

Fig 1 A case with serous otitis media. Bone conduction is considerably lowered at higher frequencies but returns promptly to normal after aspiration of the middle ear

The first histological correlation of loudness recruitment to the changes in the end-organ was obtained from cases of

Ménière's disease where the special feature, agreed upon by all investigators, was distension of the cochlear duct Special damage to the hair cells was observed by Hallpike and Cairns[4] and by Dix and Hallpike[5] in a total of three ears Other workers,[6-8] however, were not able to find such hair cell changes as could be definitely separated from postmortem degeneration On the other hand, it was common observation that ganglion cells and nerve fibers remained intact at least in the earlier part of this disease, and thus the presence of recruitment must necessarily be related to the structures peripheral to the spiral ganglion

Another histological correlation comes from the animal studies of artificial acoustic trauma [9-11] It is agreed that the lesions are primarily seen in the mesothelial cells of the tympanic lamella and in the external hair cells Following very intense stimulation the whole organ of Corti may be destroyed The lesion is also evidenced by a marked reduction of the cochlear potentials, although such a reduction may occur in ears without demonstrable histological trauma

In human material, exposed to acoustic trauma, the resulting lesions regularly exhibit recruitment phenomenon This is the case in experimentally induced hearing losses by stimulation with intense sounds[13] and in the ears subjected to occupational acoustic trauma [14]

The third histological correlation is derived from Saxen's studies of presbycusis [15] Among his 44 cases there were 13 in which the lesion was restricted to the spiral ganglion and nerve fibers and the end-organ itself was intact Another main group comprised 19 persons in which there were severe angiosclerotic changes in the stria vascularis and high grade degeneration of the organ of Corti, especially in the external hair cells, but sometimes the sensory structure as a whole was degenerated in certain areas As a rule some reduction in the spiral ganglion cells and in the number of nerve fibers also occurred in these cases In this angiosclerotic group Saxén obtained anomalous results with high intensity Weber tuning fork tests lateralization to the ear showing greater changes in the organ of Corti At the time of Saxén's clinical investigation little was known about the recruitment phenomenon, but we now know that this type of result of a Weber test is one way to demonstrate recruitment phenomenon [16]

The presence of recruitment in part of the presbycusis cases is easily demonstrated with the monaural loudness balance test Pestalozza and Shore[17] reported complete recruitment in four cases out of 20 studied It is also the experience at our laboratory that many presbycusis ears show recruitment

We must now consider closely the group of neural deafness showing prominent lesions in the nerve fibers and also in the spiral ganglion, *viz* acoustic neurinomas Dix, Hallpike and Hood,[3] who first described this group as typical nonrecruiting deafness, later[18] found recruitment of loudness in 12 per cent of the tumors Even earlier, defending his theory that the recruitment phenomenon is typical of perceptive lesions in general, Fowler[19] described one case with complete recruitment I have recently seen a case of cerebellopontine angle lesion with recruitment The explanation for recruitment in these typical neural lesions has been assumed to lie in the disturbed cochlear blood supply, which adds end-organ damage to the picture Dix and Hood[18] even described two cases in which there was recruitment prior to operation when the cochlear blood supply had presumably returned to normal

In the presbycusis group of Saxén,[15] showing only spiral ganglion cell and nerve fiber atrophy, the clinical evaluation showed no evidence of the presence of recruitment

Evidently one can safely say that, if there is recruitment, there is also an end-organ lesion, and that in a pure ganglion cell nerve fiber atrophy there is no recruitment, but there remain a number of cases in which both lesions are combined and recruitment may or may not be present It is probable that if the end-organ lesion dominates, but is not too severe, there is recruitment, and if the neural lesion dominates, there is none When these conclusions are applied to the audiological findings, we must say that positive recruitment is evidence of an end-organ lesion, but does not necessarily exclude an associated neural involvement Contrariwise, the absence of recruitment means that there is a dominating neural lesion but it does not exclude a simultaneous end-organ damage

At present we do not exactly know why recruitment occurs in end-organ lesions, although many hypotheses have been advanced to explain the phenomenon It is commonly believed that as the excitation becomes stronger, more and more hair cells are activated, especially internal hair cells, which are more resistant to damage than the external ones The resulting initial discharge would then be capable of stimulating a normal amount of nerve fibers, so that a normal loudness sensation results, however, the matter is not so clear as that If one believes that the cochlear potentials are a fair indicator of the condition of the hair cells and responsible for initiating the nerve impulses in the cochlear nerve endings, one is at a loss to understand the origin of the recruitment phenomenon

In Fig 2, which is reproduced from Wever and Laurence's recent book[20] "Physiological Acoustics," we notice first a normal cochlear potential curve obtained by increasing the stimulus and recording the increase in the potentials The lower curve describes a similar response from an ear subjected to acoustic trauma, and it shows a constant deviation from the upper curve If, in this typically recruiting lesion, recruitment were to depend upon the activity of the hair cells in the form of cochlear potentials, the curves should unite at higher intensities instead of showing the present nonrecruiting slope The results of Davis and his associates[11] suggest, on the other hand, that the maximum response is lowered less than the threshold, and it might be said to represent partial recruitment

At the present state of our knowledge I suggest that the nerve endings around the hair cell bases may possibly be important also in the origin of recruitment, although the idea that the mechanical movements of the basilar membrane might directly stimulate the nerve endings, is not consistent with the present belief, however, many of Saxén's presbycusis case records indicate good hearing even in cases where the hair cells had suffered intensive damage but the nerve endings were intact Further data on this question are required

Indirect Recruitment Tests

A number of other tests have been devised to take the place of loudness balance tests, or some have been claimed to be independently of great clinical significance In this connection I can discuss only briefly some of these tests For a more complete evaluation the reader is referred to an earlier paper [21]

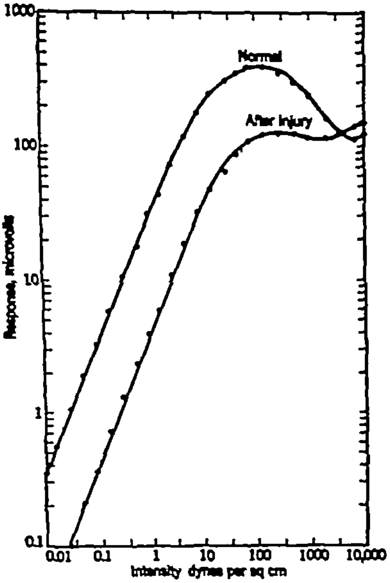

Fig 2 Intensity functions for the cochlear responses of the cat on stimulation with a 1000 c.p s tone before and after injury by overstimulation with this tone Reproduced from 'Physiological Acoustics p 295 by Wever and Laurence [0]

Together with Hirsh and Goodman,[22] I have shown that the tests for intensity difference limen do not differentiate cochlear from retrocochlear lesions the figures for IDL are of the same magnitude for both groups Our testing was done by the method of comparing the intensity of two separate tones, but there is also enough evidence to testify that the use of modulated tones[23 24] does not take us further in the differential diagnosis

The same can be applied to tests for frequency difference limen Some authors[25, 26] claim that especially an increased FDL signifies recruiting deafness and cochlear lesions, others say that this very finding is frequent in retrocochlear pathology[27] It is difficult to see how the size of the FDL could be different in these two main categories when one remembers that diplacusis, a change in pitch perception, occurs in cochlear as well as in retrocochlear lesions

Tests for either per- or post-stimulatory fatigue[28-31] have been recommended for differential diagnosis, however, control experiments have shown that abnormal results appear in the two main groups of perceptive deafness, and a large proportion of the cases show results comparable to normal[32, 36] We may take as an example continuous threshold recording at a fixed frequency which exemplifies a special kind of per-stimulatory fatigue Hood[28] has claimed that abnormal fatigability in this test is typical of an end-organ lesion, and Reger and Kos,[30] and Kos[37] have reported cases of acoustic tumors with highly fatigable ears at threshold stimulation In my experience[35] a good many cases in both groups show only minor fatigability during a four minute test, but there are cases in both the cochlear and retrocochlear group that show also abnormally high fatigue

The width of the excursions in a self-recording audiometer has also been used as a localizing test in audiometry[38] It seems true that very small excursions, indicating rapid growth in audibility, are a common phenomenon in cases with asymptotic recruitment at higher frequencies At the lower tones, below 1000 c p s, and in the groups of straight or delayed recruitment, the size of the excursions is generally larger and allows no conclusions as to the recruitment phenomenon[35]

Masked audiograms, either with white noise[39] or with saw tooth noise,[40] have also been advocated in the differential diagnosis In control measurements with critically controlled stimuli it has been shown that noise audiometry is not helpful for this purpose[41, 42]

Speech Tests

During the last decade it has been established beyond doubt that the recruitment phenomenon is accompanied with poor discrimination for speech This has been reported among others by Dix, Hallpike and Hood,[43] by Eby and Williams,[44] by Huizing and Reyntjes,[4] and in our own series [22, 46] Speech function depends mainly upon two facts, *viz* the characteristics of the language and the threshold loss for speech Using the Finnish language, which is rich in vowels, the ability to discriminate is not greatly reduced until the threshold loss exceeds 40 db[46] but using the American PB test this already occurs in cases of 20 db loss [22]

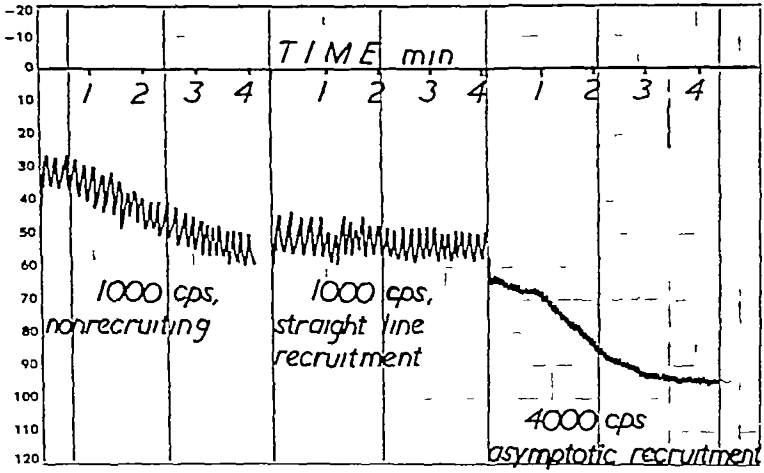

Fig 3 Continuous 4 min threshold recordings in various forms of perceptive deafness Temporary threshold shift may appear in recruiting as well as in nonrecruiting deafness The width of the tracings may remain large also in recruiting deafness especially at lower frequencies.

It was believed at first that in retrocochlear deafness, even when it is severe, speech discrimination is better than in end-organ lesions This was the experience of Dix, Hallpike and Hood[43] and of Eby and Williams[44] in acoustic neurinomas, and at least in the latter series, there were enough data of masking to convince the reader that shadow hearing was not present The ability to discriminate speech was reasonably good and increased with increasing amplification, however, increasing clinical experience brought out deviating results

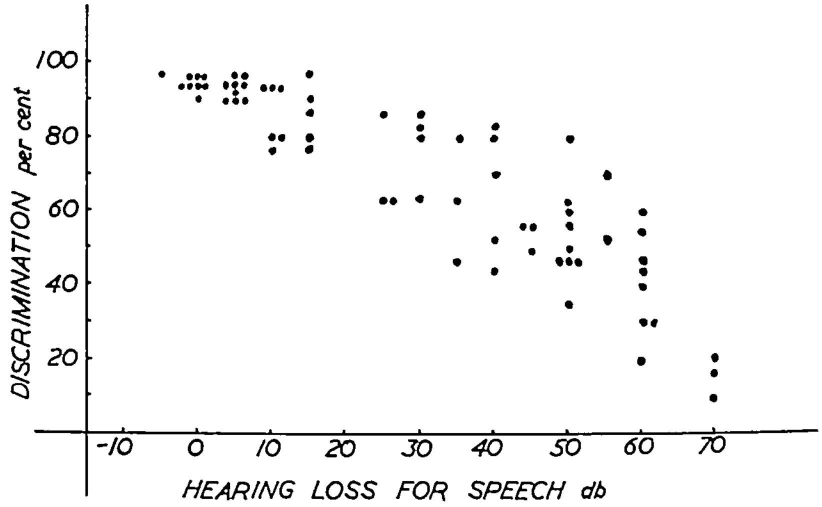

Fig 4 The relation between discrimination ability and hearing loss for speech in 69 cases with complete recruitment tested with the Finnish speech test material[46] Discrimination suffers notably when the threshold loss exceeds 40 db

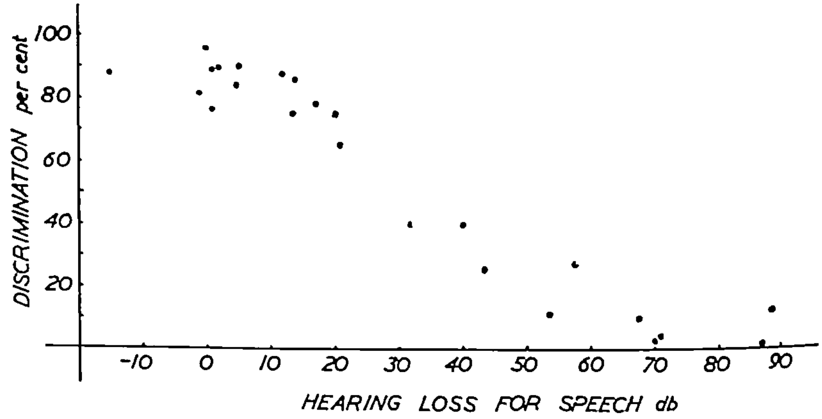

Fig 5 The relation between discrimination ability and hearing loss for speech in 27 cases with complete recruitment tested with the American PB material Discrimination suffers greatly already after 20 db threshold loss Data from Hirsh Palva and Goodman[22]

Poor speech discrimination in acoustic neurinomas has been reported in seven cases by Liden,[47] in two by Schuknecht and Woellner,[48] and in one by Harbert and Sataloff[49] The two cases of our own,[22] to which Walsh and Goodman[50] later added one, also showed very poor articulation function

In quite small threshold losses, discrimination for speech can be disproportionately poor or even nil

The testing experience at our laboratory still suggests that in nonrecruiting neural pathology, excluding acoustic tumors, speech function is lowered but reasonably good It may be that the presence of an acoustic tumor in a nerve reduces the nerve fibers to such an extent that delivery of all complex signals becomes impossible

In conclusion, we do not at present have such audiological tests as would tell us that in one case there is a pure cochlear lesion and in another a pure retrocochlear lesion with 100 per cent certainty We should, therefore, avoid depending too much on audiological tests alone Audiometric tests are an extremely important asset in case evaluation, but it must be remembered that final diagnosis can be made and the lesion located only on the basis of complete anamnestic and clinical data, supported by the results of auditory tests

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Dr. Hirsh Are there any comments on Dr Palva's paper?

Dr. Josef Zwislocki, (Cambridge, Massachusetts) I have comments on the two papers of Dr Palva and Dr Carhart

I am not quite sure when it is safe to say that the difference between bone conduction and air conduction differentiates conductive from perceptive deafness There is one thing which is established beyond a reasonable doubt today, *i e*, that the conduction of sound in the inner ear is essentially the same for air and bone conduction

DR WILLIAM G HARDY, (Baltimore, Maryland) There are gap areas in the diagnosis of hearing losses that need much work For example, we cannot offer much of value to the patient when we find nerve degeneration or an advanced case of otosclerosis There is a toxic condition that leads to nerve degeneration, but we do not know just what it is

In another area is the case of deafness caused by a single blow to the head We hear much about acoustic trauma, and shock pulses causing total deafness, but clinically, we are frequently presented with the case of a man who receives a blow to the head which is not severe enough to knock him down, yet he loses his hearing Or again, he may be knocked down, but not hard enough to cause a fracture of the skull or produce unconsciousness, but still he has a total loss of hearing I think something like this may be the result of a hemorrhage into the labyrinth

In still another area, the inner ear, we see the effects of virus disease Measles and mumps may disturb the hearing, even without an open infection A virus may attack and the lesion may be entirely in the endolymphatic system and begin, for example, in the stria vascularis and the tectorial membrane may roll up We get a greater destruction of the stria on the basal turn, in these cases, and the stria may even disappear at that point

We have many cases of deafness which we cannot explain, some of which are connected with ocular disturbances This may be a toxic involvement through the round window

Then there are the intriguing diseases, such as Ménière's disease, where there is a shift in threshold and the hearing is depressed more in the low tones Why is there only a low tone deafness? In theory this is only possible on the basis of an inner ear conductive loss, but the presence of recruitment makes this not very probable, however, the shift from a high to a normal hearing threshold may take place in only a few hours This again favors the theory of the condition of the hair cells themselves as being important

I have patients who have presbycusis *before* they developed Menière's disease Deafness seems to have been caused by a marked disturbance of the wall of the vestibule

CLINICAL ASPECTS OF CORTICAL DEAFNESS

Ettore Bocca,

University of Milan,

Milan, Italy

The clinical examination of the peripheral organ of hearing has undergone a radical evolution in the recent decades, thanks to electrophysiological investigation of the cochlea, and to the introduction of the audiometer, however, it has not had its counterpart in a better knowledge of the auditory experience as a whole

More and more attention has been devoted to audiometry, with the result that we know a lot more about hearing but as little as ever about listening Since the assertion of Collet in 1920, that we know nothing about the cortical troubles of hearing, things do not seem to have improved much until 1953, when Aboulker stated that the semeiology of the cortical disorders of hearing is still in its infancy Two years later Alajouanine, in his beautiful book on the functions of the temporal lobe, concluded that it is so far impossible to make an audiometrical diagnosis of a lesion of the auditory cortex

As far as we are dealing with the organ of hearing, physiological, physiopathological and clinical investigation may avail themselves of the same stimuli pure tones, or simple sounds Before these stimuli, the organ of hearing behaves in a well-defined fashion, according to well-known physical and mathematical laws

The appreciation of loudness casts a shadow upon the value of some physical determinations, but that problem, too, has had a satisfactory explanation on a psychophysiological basis As far as tones and simple sounds are concerned, the response in the experimental animal may be compared with the responses which are obtainable in the clinical experiment in man, however, things get more and more complicated as we consider the analysis and the identification of a meaningful message The electrical response of single cortical areas to pure tones, or clicks, provides an excellent basis for the knowledge of the limits, and the excitatory processes, of the auditory cortex, but it does not help in explaining how the cortex may elaborate the psychological aspects of a verbal message

The conditioned thresholds to sounds in the decorticated animal only prove that most acoustically conditioned reflexes take place at some level below the cortex The demonstration afforded by that animal, previously conditioned to different sequences of stimuli, which fails to give differentiated responses after its cortex has been removed, is the only experimental hint to the importance of the cortex in cortical discrimination of auditory patterns Recently, further observations upon this point have been reported The function of the auditory cortex must not be regarded as analytical, on the contrary, it is mainly synthetical The different attributions of sounds must be faithfully transmitted from the ear to the centers in order that they may be correctly recognized, but, when the sound is a meaningful verbal message, it is also necessary that they reach the centers with a certain order in space and time "Reversed" words are not comprehensible, in spite of the fact that they contain exactly the same frequencies and intensities, a poorly known foreign language is not understood if it is spoken rapidly These few facts may serve as an example that there is a wide difference between the recogntion of the physical qualities of a sound and the process of identification of a verbal pattern The former depends upon the working of the auditory apparatus as a whole, the latter is a specific function of the auditory cortex This is a very obvious and widely accepted fact, which should have long since orientated all clinical investigations of hearing at a cortical level

Otologists of many countries have been busy in recent years trying to reveal cortical disturbances of hearing by means of pure tones, which are to be considered as the specific stimulation of the cochlea, cochlear nerve, and the first stations of the auditory pathway The scanty data available in the literature are equal only to the scarce importance of the observations

If we devote some attention to the works of all the great neurologists and psychologists of the last 70 years this seems to be rather surprising In the chapters dedicated to the problem of aphasia, the way to further research in the field of cortical deafness is clearly indicated Until the physiological experiments are able to bridge the gap between form and experience (which is highly improbable) we shall be obliged, when studying sensation at a psychological level, to set apart all the traditional experimental and clinical methods, and to avail ourselves of testing material of a purely psychological value Pure tones and simple sounds must be abandoned, and words or sentences must be resorted to, because they alone own the symbolic, emotive, mnemonic, and evocative qualities which acquire their significance at a cortical level

As a matter of fact, after the failure of tonal audiometry, hearing for the voice has been tested by some authors, in cases of pathology of the temporal lobe, the results did not significantly differ from normal, so that any further possibility of audiometric investigation of the auditory cortex seemed to be precluded At the present state of knowledge there is a sharp passage, in the temporal lobe pathology, from normal hearing to word-deafness, which represents the final stage of most severe lesions We have no means of revealing audiometrically the early or pre-aphasic stages

If we bear in mind the importance of quality, space, time, and rhythm as factors governing the cortical identification of a verbal pattern, we may be easily persuaded that modern electroacoustic engineering gives us a chance of altering one or more of these factors in a way which can be exactly defined and easily repeated, an entirely new testing material may be put at our disposal, for the detection of early troubles of cortical hearing, in the same way as the audiometer reveals early and unsuspected troubles of the frequency and intensity function It is not difficult to explain why, in limited lesions of the temporal lobe, evident disorders of verbal hearing are rare events

The nervous sensory apparatus works according to a principle of redundancy, which is very common to all natural organizations As a consequence, even if a fairly large number of its structures are put out of function, sufficient contacts are always possible between the centers and the external world

On the other hand, speech also, as a means of communication, works along the same principle Every speech sound contains an enormous amount of information units, far outnumbering the minimum that is theoretically required for its differentiation from another sound, as a consequence, even if a certain number of those units get lost, due to faulty transmission or reception, the speech sound is still recognizable, moreover, if one considers the rather rigid way in which speech sounds are combined into a word, or words into a sentence, a very considerable loss of quality is necessary to make speech no longer intelligible It appears logical to suppose that the conditions for the identification of a verbal message grow more difficult if the poor quality of the message is associated with a poor working of the neural sensory structures, in other words, when a peripheral distortion is associated to what we may call a central distortion The distortion may affect intensity, frequency, and time Any alteration of these factors will alter the value of the equation

$$I \text{ (amount of information)} = 2\, t\, w \log \frac{S+N}{N}$$

(Where t is the duration of the signal, w is the width of the usable frequency range S the maximum amplitude of the signal, N the minimum discernible difference of intensity)

thereby reducing or increasing the amount of information

Other factors such as space and rhythm must also be taken into consideration, therefore, we developed a series of clinical audiometric investigations whose logical basis was that of sensibilizing the traditional speech tests by making them more difficult in several ways (cutting of frequencies, acceleration, periodic interruption, increase of the length of the message, alteration of meaning, rhythm, accentuation) Some of these tests have already been performed in an extensive number of cases of tumors of the temporal lobe, and of degenerative changes of the cerebral cortex, due to old age In all these cases traditional tonal and speech audiometry failed to reveal any significant deviation from normal Some other tests have been so far experimented with in a more limited number of cases, mainly or exclusively old-aged subjects

FACTORS AFFECTING THE CORTICAL RECOGNITION OF THE VERBAL IMAGES

Factors	Related Tests
Physical Qualities of the Verbal Pattern	Distorted Voice, Interrupted Voice
Duration of the Signal	Accelerated Voice
Length of the Message	Long Sentences or Lists of Words
Meaning	Meaningless Sentences "Reversed" Sentences (Ex the cat is on the table table the on is cat the)
Rhythm	Prosodic Alteration (Accent Shift) Aperiodic Variations of Speed, Reversed Sentences

Fig 1

1 Distorted voice Lists of PB disyllabic words have been presented monaurally at 50 db above threshold, through a low-pass filter capable of reducing discrimination to 70 to 80 per cent in the normal subject Temporal lobe tumors present an average discrimination which is poorer in the ear contralateral to the tumor (50 per cent vs 65 to 75 per cent in the ipsilateral ear)

2 Interrupted voice A discrimination of 80 per cent of PB disyllabic lists is the rule in the normal subject, if the voice at 50 db above threshold is interrupted periodically 10 times per second, the ratio voice silence being 1 1 Tumors of the temporal lobe show worse discrimination in the ear contralateral to the lesion (30 to 40 per cent less as an average)

3 Accelerated voice If the number of words per minute of the speech is increased from the normal (about 150 words per minute) to about 350 words per minute, the discrimination always approaches 100 per cent in the normal subject, however, the threshold is raised by 10 to 15 db. Tumors of the temporal lobe may present a normal threshold shift, but the discrimination never attains 100 per cent in the contralateral ear.

4. Long messages. When listening at a comfortable level, a normal subject is able to repeat 100 per cent of obvious

AGED PERSONS

Test		Response
Distorted Voice	+	Fairly Good
Interrupted Voice	+++	Very Poor in Both Ears
Accelerated Voice	+++	
Long Sentences or	+++	Very Poor in Both Ears
Long Lists of Words	++	
Meaningless Sentences	+	Fairly Good
Reversed Sentences	+++	Extremely Poor
Prosodic Alteration	+++	Extremely Poor
Velocity Fluctuations	++	Poor

TEMPORAL LOBE TUMORS

Test		Response
Distorted Voice	+++	Poor in Contralateral Ear
Interrupted Voice	+	
Accelerated Voice	++	
Long Sentences or	+++	Poor in Both Ears Only in Left Side Lesions (Right handed Pts.)
Long Lists of Words	++	

(+ indicates validity of the test.)

Fig. 2

sentences of ten words, and respectively 70 per cent of 15 words and 40 per cent of 20 words. Tumors of the temporal lobe show a very poor performance (respectively 70-10-0 per cent for monaural left and right, or binaural audition, when the tumor is located in the left hemisphere in right-handed patients. No deviation from normal is observed in right-sided tumors.

The results obtained appear to be specifically indicative of an impairment of the auditory cortex, as no similar responses have been observed in the many cases where the tumor was located outside the temporal lobe

It is interesting to note that, as far at least as the integration of a distorted message is concerned, there seems to be no real dominance of one hemisphere over the other The poorer response is always in the contralateral ear, regardless of the side where the lesion is located, however, for the function of memory, the left hemisphere in right-handed patients is clearly dominant Cases of severely increased intracranial pressure often give bilaterally poor responses

The observations made in tumoral pathology prompted us to investigate the response to the same tests in old-age subjects, showing the best possible audiometric curves in relation to age and the best possible performance in psychometric tests, and normal responses to traditional speech audiometry The results have been even more demonstrative than those observed in the group of temporal lobe tumors, of course, no difference existed in monaural tests between the response of the two ears The only exception was observed in the test of distorted voice Discrimination was better in aged subjects than in temporal lobe tumors This may be tentatively explained by the fact, that due to the progressive loss over high frequencies, the aged persons have been slowly getting accustomed to the cortical integration of messages lacking the higher portion of their acoustic spectrums

The interrupted voice test gave much poorer responses than in tumor cases The same happened with the accelerated voice test, the long sentences test gave as poor results Some of the poorer responses may depend upon the greater synaptic delay in the cortex In other cases, they may be due to the lack of partial compensation by the contralateral temporal lobe The comparative evaluation of the results of our tests in the old age and tumor group of cases is an implicit confirmation that the auditory troubles of old age are mainly cortical in origin, and that insofar as the process of cortical elaboration of the message is concerned, it does not matter whether the cortical lesions are brought about by compression and invasion, or by primary atrophic and degenerative changes

This fact has persuaded us in recent months to extend further our psychoacoustic researches in the aged subjects, who form a far more numerous and homogeneous group than tumor cases, with the conviction that the results may be a proof of the validity of new testing material, and an indication of its possible employment in the study of cortical pathology from other causes

The new testing material used consists of

1 Meaningless sentences The importance of meaning does not much affect the correct repetition of sentences, with results only 20 per cent less as compared with the control group

2 Alteration of rhythm The importance of rhythm seems to be of paramount importance in the correct recognition and repetition of sentences Rhythm may be altered by, *1* irregularly varying the output velocity of the speech, or *2* shifting the accent of words to wrong places

In the old-age group, when compared with the control group, the percent of correct responses falls respectively from 100 to 70 per cent, and from 50 to 0 per cent

These investigations further helped us to establish which functions of the auditory cortex and associated areas are more liable to be compromised, and which tests are more suitable for the detection of a cortical impairment of hearing, whose clinical evidence is a very late and very rare occurence Modern electroacoustic facilities allow us to multiply these tests, and to perform them under conditions of so far unknown reliability A first step seems to have been made in the creation of a new semeiology of the cortical disturbances of hearing

This new semeiology is not only diagnostically important, but it entails interesting physiological and psychological implications, *viz* the relative importance of crossed and uncrossed fibers along the auditory pathway, and the dominance of one hemisphere over the other, moreover it leads to a considerable widening of the term of "deafness' as it is generally accepted today, especially in old age, and offers the hope of a better solution of some of the many problems regarding prothesic adaptation and the re-education of the deaf

DR HIRSH Are there any questions or comments on Dr Bocca's paper? Dr De Sá has a comment

AUDIOLOGIC FINDINGS IN CENTRAL NERVE DEAFNESS

GERALDO DE SA,

University of Recife, Brazil

The detection of nerve deafness of central origin, is the latest trend in audiology The development of electric audiometry, and mainly of speech tests, brought a greater interest of the audiologist and the otologist in general to the possibility of the existence of a complex pathology, under the uncertain diagnostic of nerve deafness For the past five years literature has been abundant on the subject of deafness caused by tumors and traumatism, therefore, greater interest arose with the better knowledge of the possibilities of speech testing Attention is being called to the importance of speech discrimination losses for the detection of central nerve deafness since 1953 by Theo E Walsh Also, a better study of the recruitment phenomenon permitted the audiologist to separate cases of cochlear and post-cochlear nerve deafness

Perceptive aphasia was studied for a long time by the neurologist, and only recently was developed in the field of the otologist It seems to us that the two portions of the acoustic nerve, terminal organ, and acoustic pathway and brain projections, should be studied separately, being considered the cochlea as a sound selector and the pre-cortical and cortical areas as the final analyzers The audiometry with pure sounds would be, evidently, of great importance for the diagnosis of diseases of the selective organ, the organ of Corti, however, the identification of the composed sounds, and more especially of the speech sounds, being accomplished on the pre-cortical or cortical centers, would be better made with the help of testing measures that demand more intensive cerebral implication

This seems to be today, a generalized idea for the audiologists To test the perception of a word, no better testing material could be available than the word itself For all of us dedicated to the speech audiometry the importance of the discrimination tests for diagnosis soon become apparent Besides, the use of phonetically balanced word lists holding identical percentage of sounds of a language, would permit testing a patient unable to hear this language well, with material adequate for his disability

In our country, where otosclerosis affects only 15 per cent of the cases of deafness, the most common symptom brought by a patient to the otologist is to hear, but not to understand It seems to be that nerve deafness is our real toll As a matter of fact in nearly 600 cases of deafness studied in the last four years, we found about 40 per cent of cases of so-called "nerve deafness" Under these local circumstances the discrimination tests became of great importance to us

We used on our patients, for determination of discrimination score, phonetically balanced lists, prepared by ourselves at Central Institute for the Deaf, St Louis, Mo, in June, 1952 Since the beginning of the work with the phonetically balanced word lists, in September, 1952, we decided to observe a specific approach, by registering each answer of the patient, and not only establishing a curve In this way we believed we could, after enough experience, see which sounds were most commonly lost by the patient in the several diagnostic groups

Employing phonetically balanced lists, containing all the sounds of the language in identical percentage, it was easy to disintegrate each monosyllable lost, in its phonetical components, and to establish definite medias referring to all the phonems of the language This study is presented today, and might lead to interesting conclusions On the other hand a careful control of the improvement of hearing and discrimination after therapeutical measures could be established

Based on our observations, we agreed with Dr Walsh that the cases of otosclerosis showed very little discrimination loss, while the nerve deafness showed a greater one, and that a certain type of deafness showed an extremely great discrimination loss In cases of nerve deafness, some showed recruitment and some did not Those with recruitment, we named cochlear deafness, and on our charts are represented by five cases of hydropsy, three cases of toxic neuritis, and two cases of acoustic trauma

Among the cases with no recruitment, that we named retro-cochlear deafness, we charted two cases of skull trauma, two cases of epilepsy with focus on the left temporal lobe according to electroencephalography findings, one case of multiple sclerosis, one case of general toxicosis, two cases of supposed cortical deafness, and two cases of presbycusis of the Schuknecht physiological type

Among the cases of otosclerosis, ten patients with no signs of nerve involvement were chosen Their media of pure tone loss was 65 db, and their media of discrimination was 84 per cent Among the 48 phonems in the Portuguese language, 15 were heard by all the patients, 1160 phonems were given to the ten patients, and only 83 were lost, giving a media of 7 15 per cent of discrimination loss Among the phonems lost the F's came with the highest percentage, 40 per cent, followed by the S's with 35 5 per cent The D's, the B's and the AN's followed with a smaller percentage, and among the rest, the losses were very small

The cases of recruiting nerve-deafness showed a very different aspect Their media of pure tone loss was 40 dbs, and their discrimination was 70 per cent Five cases had pure tone around 20 to 25 c p s Among the 48 phonems in the Portuguese language (as spoken in Brazil) 11 were heard by all the patients From the given 1160 phonems 145 were lost, giving a media of 12 5 per cent of discrimination loss The F's were the phonems lost more often, 70 per cent, and the S's gave a percentage of loss of 63 328 per cent, the IN's and the B's followed with 40 per cent and of the diphthong AI 50 per cent was lost Of the D's 30 per cent were lost, and the Z's, UN's, V's and T's followed The rest of the phonems were in a smaller percentage It was evident that cases of nerve deafness with recruitment, lose more consonants,

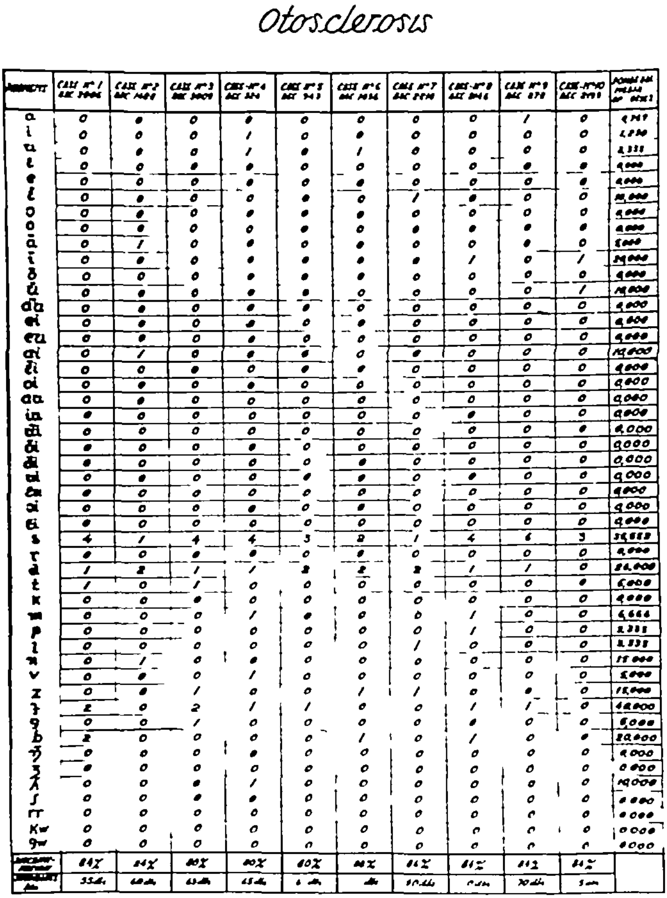
Otosclerosis

Fig 1

among them, F's, the S's, the D's, the T's and the B's One could detect the diagnosis by the almost complete losses in S's, that were scarcely heard at all Those cases showed also sloping curves towards the high frequency tones from 2000 c p s up Their bone conduction was poor, but present

Now we come to the cases that are mainly the reason for this communication—the nerve deafness cases without recruitment, that we charted as retro-cochlear deafness Their media of pure-tone loss was 45 dbs , and one case had no pure tone loss at all Their media of discrimination was 45 per cent Among the 48 phonems in the Portuguese language,

Cochlear Deafness
(Recruitment)

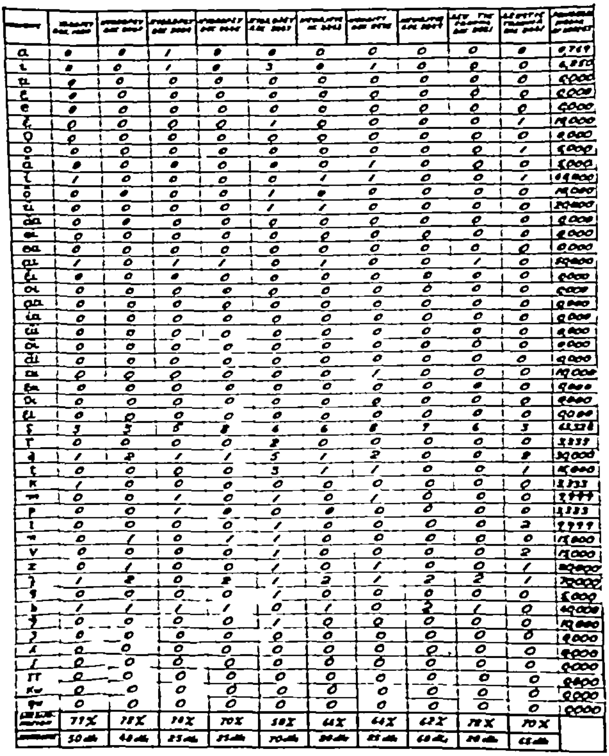

Fig 2

none escaped being lost by some patients From the given 1160 phonems, 347 were not heard, which gives a media of 29 913 per cent of discrimination loss

On the selection of the phonems lost, we saw a complete change from the other types of deafness The AN's, that until now showed practically no losses, showed 90 per cent loss The F's presented 70 per cent of losses, the IN's and the UN's showed 60 per cent, and so did NN, also a nasal sound The B's showed 65 per cent loss, and again the nasal sounds ON and the nasal diphthong AO showed 50 per cent

Retro-Cochlear Deafness
(No Recruitment)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
a	12	1	0	1	0	1	2	4	2	0	13,698
i	4	1	0	1	1	1	7	3	0	1	21,750
a	4	3	0	0	1	0	2	1	2	0	24,666
ɛ	0	0	0	0	0	0	0	1	0	0	2,000
e	2	0	0	0	0	0	1	0	0	2	14,666
ĩ	2	1	0	2	0	0	2	2	0	0	45,000
õ	0	0	0	0	0	0	0	0	1	0	6,000
o	1	0	0	0	0	0	0	1	0	1	15,000
ã	2	2	0	2	2	2	2	2	2	2	19,000
ĩ	0	1	1	1	1	0	1	1	0	0	44,000
õ	1	0	0	1	1	1	1	0	0	0	52,000
ũ	1	0	0	1	1	1	1	1	0	0	64,000
ãa	1	1	0	0	0	0	0	1	1	1	39,000
ei	0	0	0	0	0	0	0	0	0	0	4,000
ea	1	0	0	0	0	0	0	0	0	0	14,000
ai	0	0	0	0	0	0	1	1	0	0	29,000
ẽa	0	0	0	0	0	0	0	0	0	0	4,000
oi	0	0	0	0	0	0	0	0	0	0	4,000
aa	0	1	0	1	0	0	1	0	0	0	19,000
ia	0	0	0	0	1	0	1	1	0	0	30,000
ẽi	0	0	0	0	0	0	0	0	0	0	4,000
õi	0	0	0	0	0	0	0	0	0	0	9,000
ãi	0	0	0	0	0	0	0	0	0	0	4,000
ei	0	0	0	0	0	0	1	0	0	0	14,000
ea	0	0	0	0	0	0	0	0	0	0	0,000
oi	0	0	0	0	0	0	0	0	0	0	4,000
ei	0	0	0	0	0	0	0	0	0	0	4,000
s	3	6	2	4	6	3	9	0	3	5	41,777
r	4	2	0	1	3	0	7	0	1	3	31,333
d	6	1	0	5	2	2	4	0	2	2	44,000
t	4	1	1	3	2	1	4	1	1	2	62,000
k	1	0	0	1	3	0	3	2	0	2	33,777
m	2	3	0	1	2	0	2	2	1	1	46,666
p	0	2	2	1	1	0	1	2	1	0	32,222
l	6	0	0	0	0	7	8	1	3	3	44,444
n	1	2	1	2	2	0	2	1	0	1	64,000
v	2	0	0	0	1	0	1	0	1	2	36,000
z	2	1	0	1	1	0	0	0	1	0	39,000
f	2	2	2	0	2	0	1	2	1	2	19,000
g	1	1	0	1	1	0	1	1	0	0	34,000
b	1	2	1	2	2	1	1	2	1	0	65,000
[illegible]	1	0	0	0	0	0	0	0	1	0	[illegible]
ʒ	0	0	0	0	1	0	1	0	0	0	[illegible]
ʎ	1	0	0	0	0	0	0	0	0	1	[illegible]
ʃ	0	0	0	0	0	0	0	1	0	0	[illegible]
rr	0	0	0	0	0	0	0	0	0	0	9,000
kw	1	0	0	0	0	0	0	0	0	0	14,000
gw	0	0	0	0	0	0	0	0	0	0	9,000
[illegible]	34%	48%	70%	42%	36%	74%	44%	34%	60%	40%	
[illegible]	40 db	45 db	35 db	60 db	53 db	70 db	65 db	60 db	53 db	60 db	

Fig 3

loss, while another nasal phonem, the EN, showed 45 per cent The T's lost 50 per cent, and the B's 65 per cent, the S's 47 per cent, the M's 46 per cent, and the L, an easy phonem in Portuguese, 46 per cent loss The K's, V's, Z's and G's all showed losses up to 30 per cent

It was interesting to observe the discrimination of phonems lost by other types of patients, and the appearance of fantastic answers, difficult to find in other types In the ten patients, more than 50 fantastic answers were given, which raises the percentage to more than 10 per cent Although showing heavy loss, the S's were relatively well heard compared with other types of deafness Mistakes among consonants were very common The most frequent were F for S and T, T for D and D for T, P for T, and D and F for S Among the cases, we have charted two skull traumas without any other disablement than dizziness and deafness Case No 2986 does not respond to any caloric excitement in either ear, the two cases of epilepsy showed abnormal encephalogram with focus of slow activity in the left temporal area with sharp and spiky waves on the left anterior temporal zone Case No 2892 showed, in the Cawthorne-Hallpike test, directional preponderance for the left Examined thoroughly by the neurologist, Dr M C Barros, no other nervous symptom was found It would be interesting to note that another patient with focal epilepsy on the right side showed no loss of discrimination worthwhile, pure-tone media around 40 dbs and discrimination score 90 per cent

One case of multiple sclerosis had a linear, flat curve around 55 dbs, no bone conduction, and a very poor discrimination It has been followed now for six years and hears nothing at all for the last two years Regarding the general toxicosis, one patient has for a long time taken alcoholic drinks to excess and has a great difference between the left and right ears with very bad discrimination in both Hearing in one ear is today almost lost, and the other almost as bad, as he continues the same habit

Other cases of supposed cortical deafness refer to a patient with almost normal pure-tone level, and great discrimination loss, and another with great loss of discrimination and pure tones, that recurred with clinical treatment to a 90 per cent discrimination score, this patient being long underfed because of religious motives The two cases of presbycusis showed no recruitment and no history of toxidity and could be put in the class of general senile breakdown

We could not find in any examination signals that could be referred to lesions on the pathway between the cochlea and the cortex, but we are convinced that patients with flat pure tone threshold, great discrimination loss, mainly of nasal sounds, many consonant mistakes, frequent senseless answers, no recruitment, bone conduction very low or absent, have retro-cochlear deafness and if all these signals are backed by the existence of directional preponderance or electroencephalographic findings, cortical deafness could be suspected

SUMMARY

The author presents several cases of central deafness, some of them confirmed electro-encephalographically, and studies their audiological findings

a Tono-audiograms are presented for each case, emphasis being placed on the linear aspect of the curves

b Portuguese speech tests performed, showed some errors that became characteristic, therefore the author states the need of speech tests (logo-audiometry) being made specifically, and not only numerically, *i e*, each word must be registered by the examiner as repeated by the patient, so as to permit further observation of the results obtained with treatment, as well as to identify certain hearing losses The following observations were made

First, Nasal sounds are normally lost in central deafness (An, En, In, On, Un)

Second, The S's are well perceived while they are the first to be lost in the cases of cochlear deafness

Third, There is great recurrence of mistakes of certain consonants as T for D, D for T, F for P, P for T, (percentual is given)

Fourth, Frequently fantastic answers are obtained

c As a clinical aid to the diagnostic, the Cawthorne-Hallpike test will show directional preponderance in some cortical deafnesses

d The author fails to find a differential diagnosis in the cases of deafness by envolvement of structures between the cochlea and the cortex, but assumes that patients with linear tono-audiograms, no recruitment, no directional preponderance and negative encephalographic chart, will in most cases have lesions in the tuberculum quadrigeminus inferior or in

the medical geniculate body or in the nuclei of the acoustic pathway

DR. HIRSH Thank you, Dr Sá Any other questions or comments?

UNIDENTIFIED DOCTOR Excuse my very bad English, but I was impressed by what Dr Sá said, because we made the same investigation, and in Spanish words, to have in the corresponding language different quality deep tones

DR GREINER When you have a very strong amplification your distortion becomes greater than when you have a middle amplification When you have a peripheral or cochlear distortion this remains the same on every level of intensity When you have a cortical lesion your distortion first diminishes and then, when the distortion goes up, you have a greater discrimination

DR. HIRSH Tomorrow you will hear the physiologists tell us about the cortex, and how they will interpret some of the clinical results of today

PENDULUMS, TRAVELING WAVES, AND THE COCHLEA

Introduction and Script for a Motion Picture[*]

G V BÉKÉSY,

Harvard University,

Cambridge, Massachusetts

I INTRODUCTION

The purpose of this film is to make us familiar with the properties of traveling waves which seem to play a role in hearing Only transverse waves are described, since the movements of the basilar membrane seem to be of this sort The vibration amplitudes on the human basilar membrane, during stimulation with even a very strong sound, are so small that it would be very difficult and expensive to photograph them For this reason the traveling waves are demonstrated on models These models have the great advantage that they permit us to investigate several different phenomena as a function of a number of variables

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[*] This film originally scheduled as a portion of the session on the Physiology of Hearing was shown Tuesday evening May 14 in the clinics and laboratories of the Central Institute for the Deaf, St. Louis Missouri.

In the beginning of the film it is demonstrated that, even with an oscillating system made up of only two coupled pendulums, the energy of one pendulum does not stay attached to the pendulum in motion, but through coupling, is transmitted to the second pendulum Naturally, if there are several pendulums coupled together, the energy flows through one pendulum to its neighbor, and in this way a traveling wave is formed In general, the same holds for membranes or for any system of this type

Propagation, reflection and standing waves are illustrated, and it is demonstrated that even with a set of coupled resonators, such as those described in the resonance theory of Helmholtz, transients always produce traveling waves

The film closes with an enlarged model of the cochlea On the model the nerve supply is represented by the sensory nerves of the human skin It is the skin which picks up the traveling waves along a plastic membrane The vibrations felt are similar to those on the basilar membrane of the human ear, and they produce a sensation which is very sharply localized along the membrane even though the maximum of the vibration amplitude distribution is quite flat Changing the stimulating frequency makes the sensation move up and down on the skin of the arm, thus permitting frequency analysis by place determination

II SCRIPT

This film illustrates the principles basic to the complicated vibration pattern of the inner ear

Part I shows the production, propagation, and reflection of waves in a system of coupled pendulums

Part II shows traveling waves similar to those observed in the inner ear

Part III shows an enlarged dimensional model of the vibrating parts of the cochlea

Part I—System of Coupled Pendulums

The pendulum system consists of a series of green balls *B*, each suspended from the supporting rod *A* by a thread (see Fig 1) Adjacent pendulums are coupled by small orange balls attached between them When the large driving pendulum is coupled to the supporting rod, it sets the whole series in motion simultaneously, when it is coupled to the series only (by an orange ball) it sets the first pendulum in motion

In a system of two coupled pendulums, when one is set in motion it transfers its energy to the other, which in turn returns the energy to the first

As the coupling is increased, by lowering the coupler, the amplitudes of the coupler become larger, and the energy transmission is, therefore, increased

When there are four pendulums, the energy travels a greater distance from the point of origin

In a long series of pendulums the coupling transports energy away from the source and forms a traveling wave

The formation of traveling waves under special conditions

In the inner ear the driving forces act on large sections of the vibrating system This distribution of forces can be simulated in the pendulum system by setting the driving rod in oscillation When all the pendulums are of the same length and all are driven simultaneously, they swing in phase and no waves are produced The height of the coupling balls is immaterial

If the driving forces act on only half of the pendulum series, traveling waves develop in the center and spread in both directions When the distribution of forces is constant, a discontinuity in the lengths of the pendulums will also cause waves to spread in both directions from the discontinuity, however, when the driving frequency is lower than the resonant frequency of the pendulums, no waves are

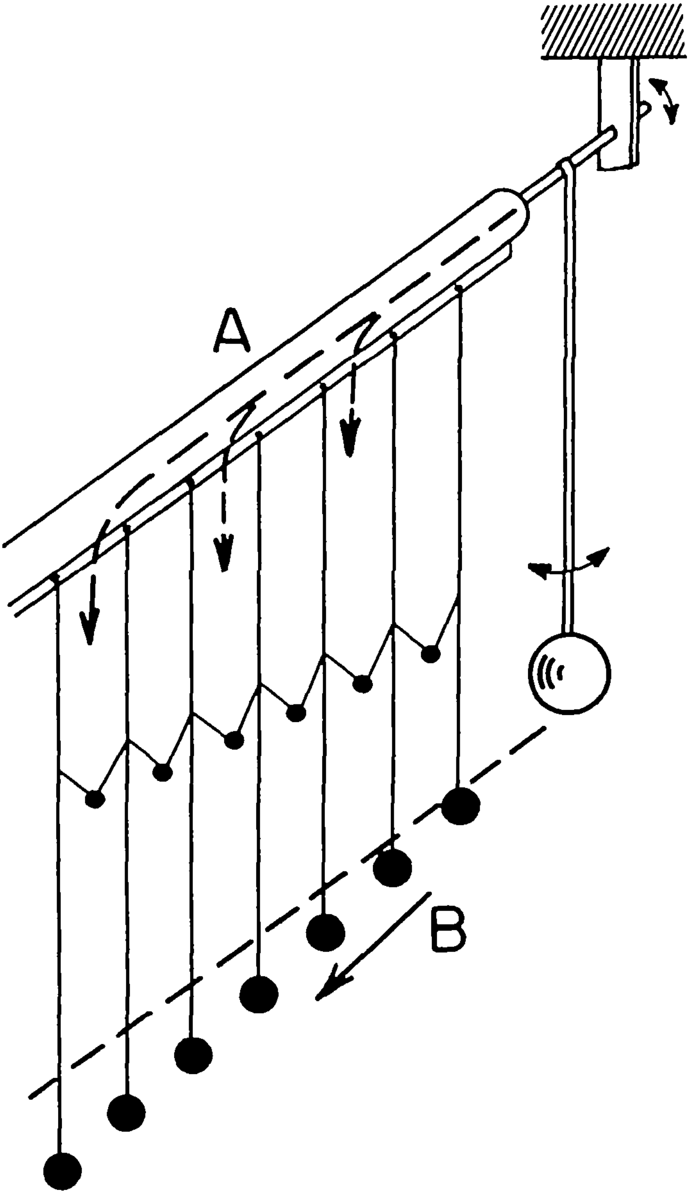

Fig 1

formed, even though the force acts on only one end of the series

Propagation of Waves

When an oscillation is suddenly transmitted to one end of the coupled pendulum series, traveling waves of varying speed are produced The high frequency components of the transients produce short waves, and these waves travel faster than the long waves This is called dispersion In a dispersive system, two types of velocity can be seen, phase velocity and group velocity

Phase Velocity—the maximum of the small sinusoidal waves moves quickly from right to left and disappears at the front edge of the group (see Fig 2)

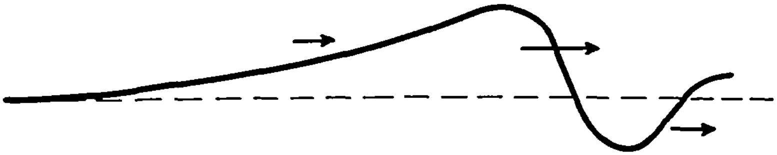

Fig 2

Group Velocity—the whole group of sinusoidal waves moves into the region of the undisturbed pendulums at a much lower velocity With smaller coupling the difference between group and phase velocity is even more pronounced

When the oscillation is continuous, however, only the phase velocity can be observed In order for us to see group velocity, transients are necessary The wave length for a given frequency depends upon the amount of coupling When the coupling is large, the waves are long When the coupling is small (the orange balls high) the wave length is small

Reflection

Whenever a traveling wave reaches a discontinuity, total or partial reflection occurs and standing waves may appear Standing waves are characterized by nodes and loops in fixed positions Usually the movements of adjacent loops are out of phase (see Fig 3)

In the picture an electro-magnet holds one of the central pendulums in a fixed position, and standing waves occur between the stationary pendulum and the driving source The moment the pendulum is released traveling waves occur and move along the whole system A local discontinuity in a traveling wave produces standing waves as a consequence of reflection

Part II—Two systems illustrating traveling waves similar to those observed in the inner ear

A system of pendulums can simulate the vibration pattern observed in the cochlea of a living guinea pig or in a prepara-

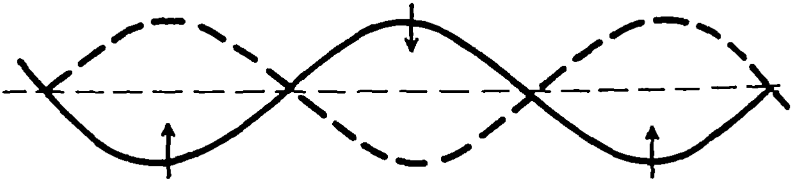

Fig 3

tion of human temporal bone When the lengths of the pendulums decrease continuously from one end to the other, what we observe is traveling waves moving in the direction of the longer pendulums For the past 100 years Helmholtz's theory has dominated the field of hearing

Helmholtz Theory

Lord Kelvin photographed Helmholtz in his laboratory in 1894—the age of kerosene, gaslight, and basic research According to the resonance theory, there are free resonators in the inner ear, each of which resonates at a different frequency Without coupling, the pendulum series becomes a system of free resonators The short pendulums at the far end are fast moving, the long ones at the front are slow moving

Traditionally, it has been assumed that traveling waves do not occur in a system of free resonators, but when the whole support of the pendulums is set in oscillation at a high frequency, a traveling wave develops at the onset of the oscillation Its maximum amplitude is in the region of the shorter pendulums As the driving frequency is lowered the maximum moves toward the longer pendulums

Transients are important in the recognition of speech and music For transients there is almost no difference between the resonance and traveling wave theories of hearing

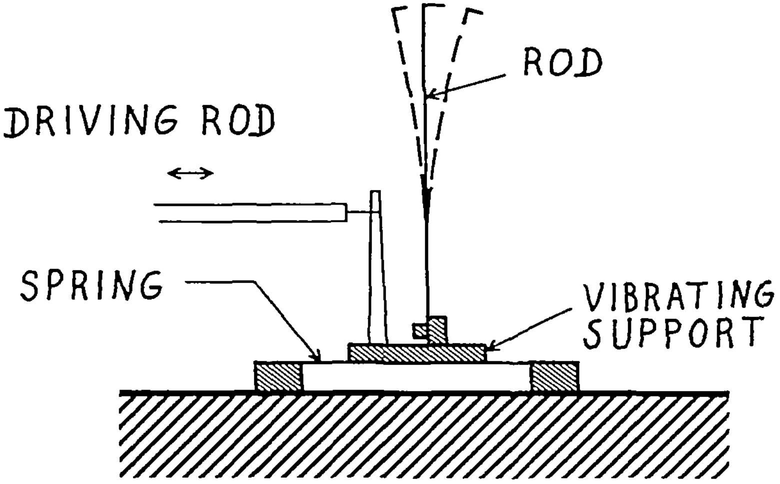

Fig 4

Reed System

In the following pictures, the same phenomena are illustrated with a series of reeds attached to a supporting base which can be set in vibration by a driving rod The reeds are tuned at equal intervals and their resonant frequencies are within the range of hearing The reeds in front are stiff and resonate at higher frequencies, those in back at lower frequencies (see Fig 4)

Applying a sinusoidal vibration to the support sets the reeds in motion Reeds that resonate at frequencies close to the driving frequency vibrate at the largest amplitudes As the driving frequency is lowered, the region of maximum vibration shifts toward the low-frequency reeds

The reeds shown vibrate 60 times per second, and only a blur could be seen, but when the pictures are projected 100 times slower, the movements of each reed can be followed The white line made by the tips of the reeds describes a vibration pattern characteristic of free resonators

The reeds below the resonance point—the point of maximum vibration—are vibrating 180 degrees out of phase with the reeds above the resonance point (see Fig 5)

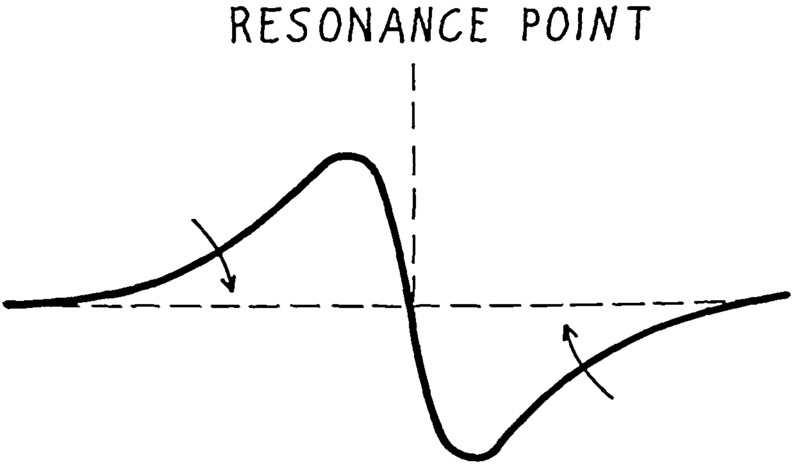

Fig 5

In spite of the assumption that traveling waves do not occur in a system of free resonators, they can be seen forming during the onset and termination of a periodic driving force The resonance theory of hearing assumes the vibration pattern you have just seen, that is, resonating elements vibrating freely

In the basilar membrane, however, each element is coupled to its neighbor This coupling is simulated here by inserting a rubber band along the reeds With the reeds thus coupled, displacement of one reed moves its neighbor

Because the driving rod is atached to the supporting base, all the reeds are exposed to the same driving force As in the coupled pendulum series, traveling waves are present, even for continuous vibrations In order to avoid reflections, damping has been added in the form of a piece of sponge rubber At normal speed we would see only the amplitudes of the vibrations moving along the row of reeds

The traveling waves are similar to the waves produced in the cochlea of an anesthetized guinea pig or in a preparation of the human cochlea, but in the cochlea there is better damping

In an elastically coupled reed system, a traveling wave does not lose energy as it travels When the wave strikes an obstacle, such as the end of the reed system, it is reflected, and standing waves result The same phenomenon is shown at normal speed and in slow motion The adjoining parts of the basilar membrane are coupled in part by the fluid surrounding the membrane

If we remove the rubber band from the reed system and immerse the reeds partially in water, the resulting frictional coupling produces traveling waves similar to those produced with elastic coupling The next picture shows the combined effects of both types of coupling As the frequency is lowered continuously, the point of maximum amplitude moves in the direction of the low-frequency reeds

Paradoxical Waves

The lower part of the next picture shows the wiring diagram of a low-pass filter, the upper part represents the voltage across each section The waves move from left to right, but with a high-pass filter the waves move from right to left, that is, toward the source of the energy Waves traveling *toward* the source are common in electrical networks but are rarely seen in nature Experiments show that they can occur in the cochlea

We can duplicate these paradoxical waves in the reed system by exerting a driving force on a whole section of damped reeds simultaneously When this is done, the driving force can be moved a certain distance along the reeds without changing the *direction* of the waves

Part III—A model of the cochlea with nerve supply

It is hard to imagine how traveling waves act on the sensory nervous system Our best approach is through an experiment With dimensional analysis we can make models of ships and airplanes that simulate all the phenomena of full-scale vessels In the same way we can contruct an *enlarged model* of the cochlear duct that incorporates the mechanical data of the human cochlea Several such models have been constructed, of which the most recent is in Gottingen

The model used here consists of a plastic tube with a membrane that is thicker at one end than at the other The tube is filled with water and at the thick end contains a vibrating piston corresponding to the stapes footplate

Sinusoidal vibrations produce traveling waves on the membrane The maximum of the vibration is close to the piston (stapes) for higher frequencies

When the forearm is placed on the vibrating membrane, even though the maximum is broad, the sensation is concentrated in a small region of the skin As the frequency changes the locus of the sensation moves along the arm

The subject moves a pointer along his arm to show the locus of the sensation for a given frequency The sensation extends over only 2 or 3 cm , as is shown by the small oscillating movements

Preparations of the cochlea show that there is in the inner ear a vibration pattern with a broad maximum whose locus changes with frequency, and experiments indicate that the nervous system sharpens this maximum

At the low frequencies the nervous system can perform a frequency analysis by responding directly to the frequency of the vibration, but at the middle and higher frequencies only the locus of the maximum determines the pitch

The impressive factor of this neuro-mechanical model is that it can perform a frequency analysis much more quickly than can any known electrical filter system

The locus of the sensation on the skin is determined with equal accuracy whether the frequency is presented for a second, or for as little as 2 cycles—which in this experiment is 0 02 second

For all our technical skill when nerves are involved, nature is far ahead of us

Acknowledgment

The electronic equipment used in these experiments and the shooting of the film were achieved with the collaboration of Rufus L Grason

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Background information concerning the patterns of traveling waves in the cochlea and on the conditions of appearance of traveling waves will be found in the following articles

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The impressive factor of this neuro-mechanical model is curious, the better off is the clinician, and there is no other area of auditory function that has so clearly shown this picture of basic knowledge contributing to successful clinical procedures than studies of the sound conduction process of the middle ear

We see the successful beginning of middle-ear surgery back in 1890[6] with attempts at mobilizing ankylosed stapedes Through many variations this procedure was replaced by the fenestration operation, first tried in one form or another around 1900,[7] and finally perfected to a single stage, and highly successful method, by Lempert some 15 years later[5] Actually it was the success of this operation that inspired some concentrated research on the conductive processes of the ear, and as a result of the subsequent understanding of the middle-ear mechanics there has been developed a number of operative procedures for the reconstruction of chronic middle-ear conditions that up to now caused deafness that had to be lived with

Our purpose here is to consider the way sound is transmitted through the middle ear and the principles of sound conduction that are involved Because of time limitations the discussion is confined to two topics, the mechanical operation of the middle ear, and the fidelity with which the middle ear performs

Of the peripheral structures the sensory cells of the organ of Corti are the most important To have hearing these cells must be vibrated, and to survive they must be nourished Because of their sensitivity to vibrations they cannot be nourished by any system that contains elements that might pulse or produce rapid movements through turbulent fluid flow, so we find these cells surviving without any direct blood supply but by being immersed in a fluid medium which moves imperceptibly, bringing nutrient material to the cells and carrying away waste products Hearing results when the desired vibrations are introduced into this fluid medium and are effectively transmitted to the cells

By placing a needle electrode in the vicinity of the cochlea and recording the potentials that arise from vibrations of the

WEDNESDAY MORNING SESSION,

May 15, 1957

PHYSIOLOGY OF HEARING

The International Conference on Audiology reconvened at 9 30 A M, in the Auditorium of the Washington University School of Medicine, St Louis, Missouri, Dr Harvey Fletcher, Director of Research, Brigham Young University, Provo, Utah, presiding as Chairman

DR FLETCHER We are to discuss today how the ear works, and the physiology of hearing The transmission of sound to the ear, through the middle ear, and into the cochlea, has been divided into two parts first, that part concerned with the process of sound conduction through the middle ear, second, transmission in the cochlea

PROCESS OF SOUND CONDUCTION*

MERLE LAWRENCE,
University of Michigan,
Ann Arbor, Mich

Many of us involved in the field of hearing do research out of curiosity We would like to know how the ear works The clinical otologist, on the other hand, is interested in how the ear works because he would like to know what to do when infection or trauma interfere with normal function Specifically, he would like to know what certain steps that he might take would improve the performance of this disarranged mechanism, so the more basic knowledge revealed by the

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*From the Physiological Acoustics Laboratory University of Michigan Ann Arbor Mich Preparation of this report was supported by the Research and Development Division Office of The Surgeon General Department of the Army under contract No DA-49-007-MD-634 and by the funds for Research in Human Resources University of Michigan

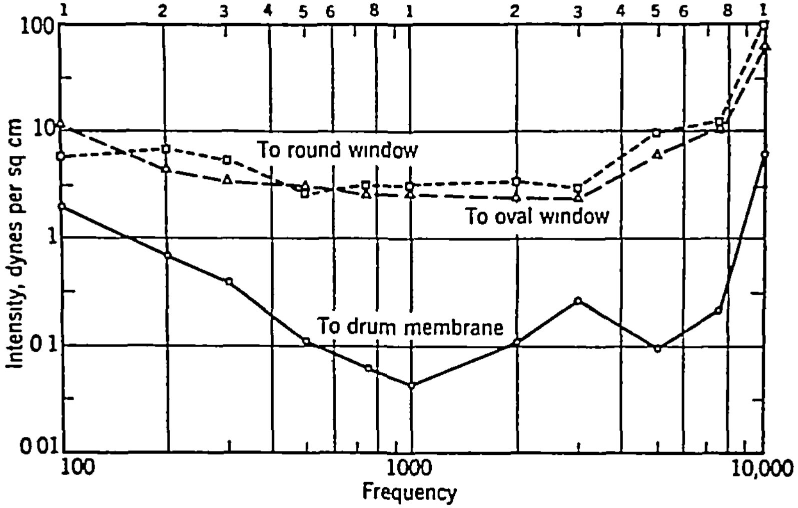

Fig 1 A comparison of oval-window and round-window pathways after the middle ear has been removed The ordinate shows the sound pressure necessary to produce 10 microvolts of response at the indicated frequencies 1 dyne/cm² is equivalent to 74 db above 0002 dyne/cm² From Reference 10

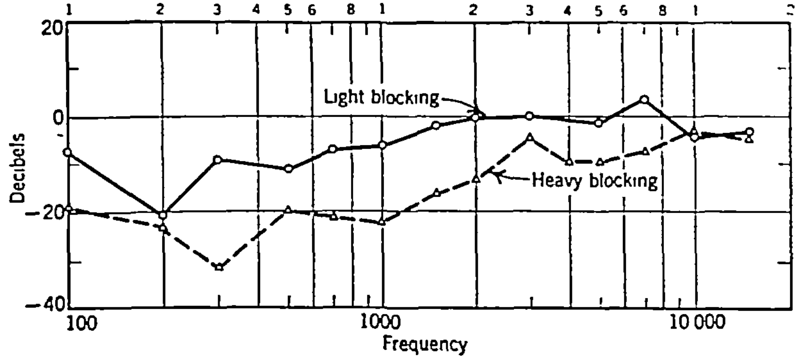

Fig 2 The effect of blocking the round window upon the response to sound delivered via the oval window From Reference 10

bubble one million times this size, about one-third of a cubic millimeter, would allow almost complete freedom of the fluid movements

Fig 2 presents the result of such an experiment The effects of two degrees of blocking are graphed to show something of the range of effects that can be obtained The decresensory cells, it is possible to obtain a measure of the efficiency of vibrations introduced into the inner-ear fluids Since there is no threshold or level of sound at which the potentials suddenly appear, it is necessary to use some constant voltage output in response to sounds of different frequencies as a measure of the ear's sensitivity By recording the sound pressure necessary to produce this pre-established level of response at the various frequencies in the normal ear, and comparing this with the responses under experimentally altered conditions, it is possible to obtain a quantitative measure of the effects of the abnormal conditions

For the purposes of simplifying the analysis of middle-ear function let us start with the condition in which there is no middle ear, the inner ear being bounded on the lateral side by the oval and round windows Our first concern is whether one of these air-conduction routes is more efficient than the other

Sound is first conducted by means of a small probe tube to the oval window and the sound pressure necessary to produce our pre-established response level measured by means of a calibrated probe-microphone system The sound is then conducted to the round window and these measurements repeated Fig 1 shows the result of such an experiment As is to be expected, considerably more sound pressure is needed to produce the required response when the middle ear is removed than when it is present, but it makes very little difference for effective vibration of the inner ear whether the sound is introduced into the oval window or the round window

Because the two windows lie at opposite ends of a fluid system, it has long been suggested that a back and forth movement of this fluid column is essential for sensory-cell stimulation This can be determined by carrying the above experiment a step farther While the sound is being introduced into the oval window the round window can be blocked This is a rather difficult thing to do effectively because the actual volume displacement of the fluids of the inner ear is so minute It amounts to the volume of a sphere with the diameter of a red blood cell when the ear is stimulated by a sound of 1000 c p s at 74 db above 0002 dynes/cm^2 An air pressure phase and pulling it out during the negative pressure phase If both windows are being pushed in at the same time the situation would be the same as blocking one of the windows, because no relief opening is available for either source of sound This condition is portrayed schematically in Fig 4 It can be seen that in such a phase relationship no movement of the basilar membrane with subsequent sensory-cell stimulation is possible This is equally true of the phase

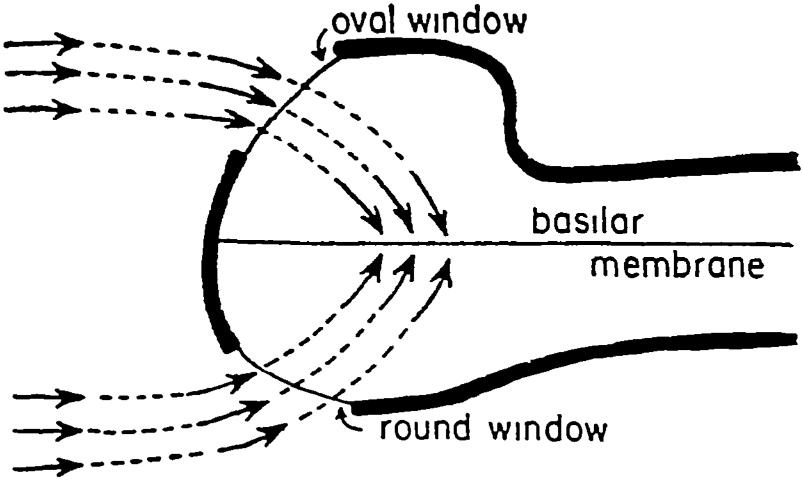

Fig 4 Schematic representation of sound entering both oval and round windows at the same time The phase condition represented here is such that there would be complete cancellation of response The sounds are in phase at the two windows and of equal intensity From Reference 11

relation when both windows are being pulled out at the same time, however, when one window is pushed in by a positive sound pressure and the other window is pulled out by a negative pressure brought about by delaying the sound by one-half a wave length, the effectiveness of the relief opening is enhanced By such a situation the amplitude of vibration of the basilar membrane should be double that produced by sound in one window alone

Again, by recording the electrical responses of the cochlea it is possible to obtain a quantitative measure of the above. Sound from one electronic oscillator is used with the output ment is greatest for the low frequencies, and is in excess of 20 db for those below 1000 c p s It is necessary to dry the surfaces and pack the niche completely with wax in order to produce the results shown It is apparent that the oval window pathway is effective only as long as the round window is free at the other end of the system

We find also that the oval window must be free to make the round window pathway effective Because of the presence of the footplate of the stapes it is easier to block the oval window than the round window, and by embedding the stapes in wax the results of Fig 3 are produced Now the effects are most severe in the range immediately above 1000 c p s, indicating that the method of blocking the two windows has changed the frequency response properties in different ways, but the principle is still demonstrated that in order for vibrations entering by one window to be fully effective in stimulating the sensory elements, the other window must be free to act as a relief opening at the other end of the system This was a theory first expressed by Edward Weber[8] more than a century ago

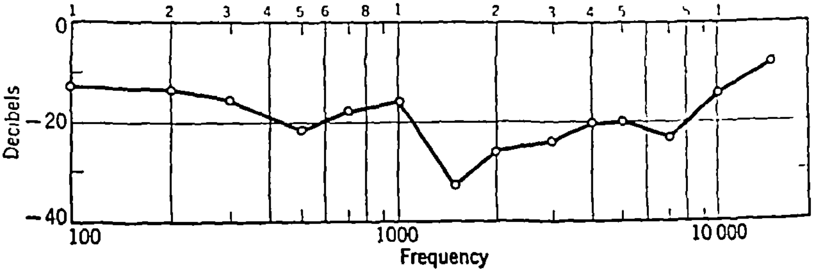

Fig 3 The effect of blocking the oval window upon the response to sound delivered via the round window From Reference 10

This principle can be studied more quantitatively if we introduce sound into both windows at the same time Such a situation would exist in an individual with no tympanic membrane or ossicles, so that both windows were exposed to the same sound field Visualize the alternating positive and negative sound pressure of a sound wave reaching one of the windows as pushing the membrane in during the positive the cochlear response as the phase of the sound in one window is shifted with respect to the phase of the sound in the opposite window The sound is first directed into one window alone and set at a sound pressure sufficient to give rise to a response of 10 microvolts This tone is then shut off and that directed toward the opposite window set to give a 10 microvolt response For the readings shown in the figure the tones are introduced into the two windows simultaneously The response shows what is to be expected from the vectorial sum of two sine waves of equal intensity when one is varied in phase As expected, in a phase relationship where one window is pushed in while the other is pulled out the response is double what sound in one window alone would give, and when they are 180 degrees from this condition, that is, both windows being pushed in or pulled out simultaneously, the response is completely cancelled The interesting thing to note is that as the phase varies through the complete 360 degrees, the two-window response is as good or better than that from one window alone over a phase difference of 240 degrees, while the two-window response is worse over only 120 degrees It is not likely that the sound, under conditions where both windows are exposed, hits them in the exact phase relation for cancellation In the first place the windows are not in exactly the same plane, considered from the point of view of the sound-wave front, and secondly, one window contains a stapes or footplate and the other a membrane These introduce phase differences, as will be shown shortly, and it does not take much of a phase shift to bring the response up to a level of that given by stimulation through one window alone If the two windows were exactly alike they would have to be separated by a distance of about seven inches for a frequency of 1000 c p s In the scheme behind our phylogenetic development this apparently was considered impractical

Another factor influencing this two-window summation is the intensity of the tones introduced Complete cancellation depends upon equal intensities, so this unwanted condition can also be avoided by the introduction of a more intense sound in one window than the other To accomplish this advantage has been taken of a fact which make a fluid-filled

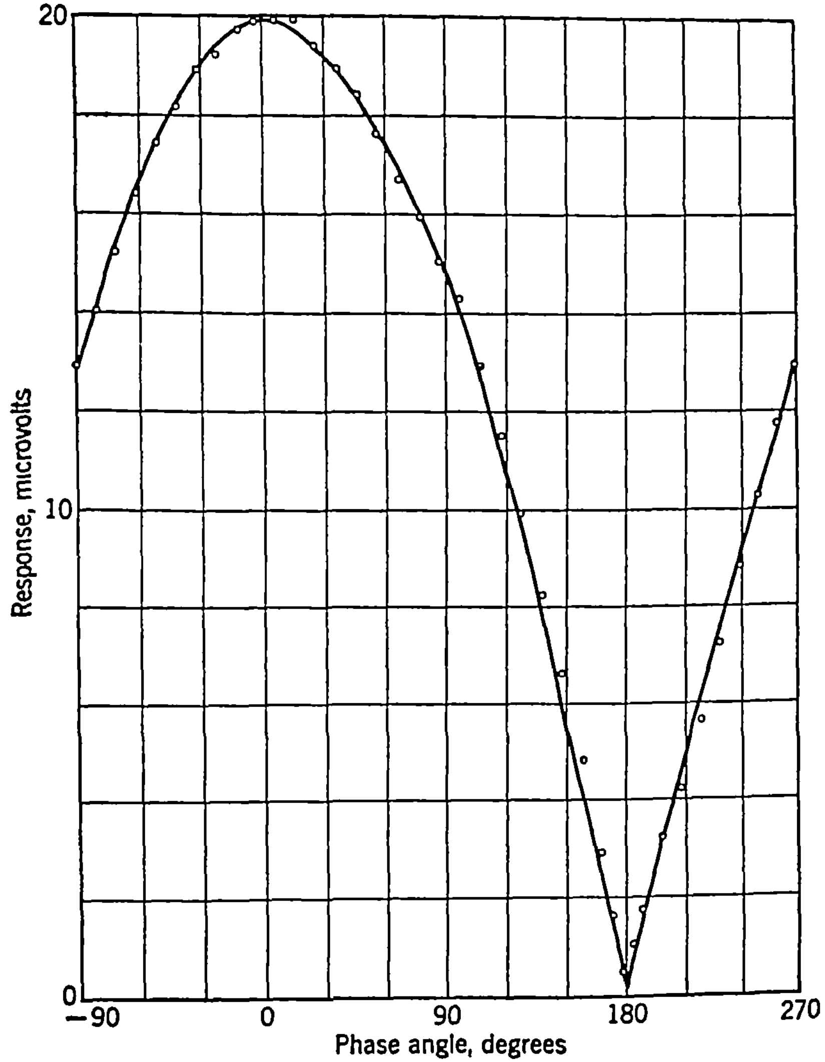

Fig 5 Vectorial summation in the cochlear response to a tone introduced simultaneously by way of the oval and round windows The phase relation of the two pathways was varied over a range of 360 as shown on the abcissa The points represent observations and the curve represents theoretical summation From Reference 10

passed through a dividing network Into one channel a phase changer is introduced and the two sources separately led, by means of small tubes, to each window The sound level is again recorded by a calibrated probe-microphone system, and the recorded electrical potentials serve as a measure of the effectiveness of the stimulus Fig 5 shows the magnitude of because of the resonant properties of the middle-ear structures, but the average is approximately 28 db, which is close to the theoretical loss of 30 db It means that, considering the errors which can be attributed to the nature of the experiment, the middle ear of the cat is almost perfectly efficient

Since the time of Helmholtz much research and thought have gone into the problem of how the middle-ear structures accomplish this match Of the theories of action that have been proposed, two have been shown experimentally to contribute to the impedance matching process

The first of these depends upon the *areal ratio* between the tympanic membrane and the footplate of the stapes In man the average of the available data shows this ratio to be about 21 to 1 Considering the fact that the tympanic membrane is not like a piston, but rather like a stretched membrane attached around the edge, the effective area of the membrane must be reduced by about one-third, making the ratio 14 to 1

The second characteristic of the middle ear that aids in the matching process is the *lever ratio* brought about by the peculiar arrangement of the ossicular chain Measurements of this in the human are few and probably not very accurate Dahmann[3] made what are probably the most reliable measures, by placing small mirrors on the drum membranes and then on the long process of the incus The ratio so determined was found to be small about 1 3 to 1

The product of the areal ratio and the lever ratio give us the transformer ratio of the entire middle ear, which then amounts to approximately 18 to 1 This pressure increase at the footplate of the stapes is equivalent to 25 db, which is not enough to overcome completely the theoretical loss of 30 db , but these figures should not be taken too seriously because of the limitations in both the experimental data and theoretical calculations In calculating the theoretical 30 db loss in the passage of sound from air to the fluids of the inner ear, data for boundless media were used, whereas the air of the middle-ear cavity or fluids of the inner-ear space are far from boundless On the other hand, data used to determine the areal ratio are limited, and the data of the lever ratio may ear quite impractical in an air environment, as was the case some 250 million years ago, when the predecessors to the amphibians first found themselves on land

Because of the extreme differences in the properties of elasticity and density between air and liquid, approximately 99 9 per cent of the acoustic energy is reflected back at an air-water interface This means that there is a loss of 30 db in transmitting the vibratory energy from the air to the inner-ear fluids By the use in one window only of a mechanism that matches these properties of air and water, it is possible to overcome both of the disadvantages of the two-window fluid system *1* the cancelling effect of equal-intensity, in-phase sound entering by the two windows is overcome by increasing the intensity in one window by 30 db over that in the other, *2* the loss in transmitted energy due to the air-liquid interface is overcome by matching the properties of air to those of the denser liquid, and this apparently is just what the middle ear does

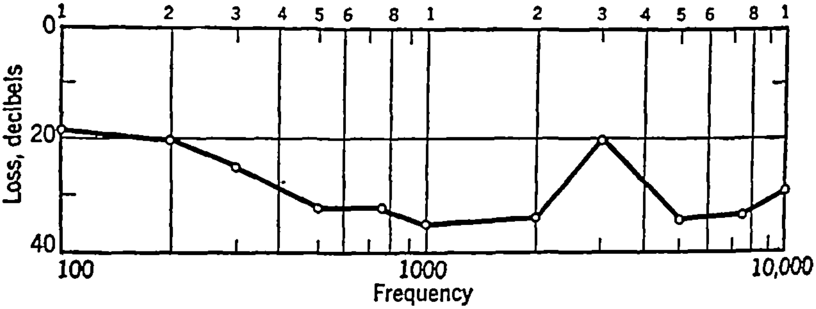

Fig 6 The loss of sensitivity resulting from the removal of the middle ear mechanism in the cat From Reference 10

To see whether the middle ear is actually performing this function, and if so, how efficiently it is accomplishing the impedance match, we can again resort to an animal experiment, recording the electrical responses of the cochlea under conditions in which the ear is normal and those in which the middle ear is removed Fig 6 represents the loss, in the cat ear, resulting from removal of the middle ear structures up to the stapes The loss is not the same for all frequencies, structures by a tone of the same frequency, but adjustable in intensity, applied through the round window A determination of the current in the cancelling receiver gave a measure of the volume displacement He then repeated the balancing process after removing all of the middle-ear structures, including the stapes and round window, by conducting the sound directly to the fluids of the inner ear through the oval and round window openings These results showed considerably larger volume displacements at low frequencies than before, but their magnitude showed a progressive decrease as the frequency was raised until, at the higher frequencies, they became smaller than in the intact ear

Fletcher[4] divided the first set of values by the corresponding ones in the second set, and regarded the quotient as representing the transformer ratio of the middle ear The calculations, which he interpreted as demonstrating a middle-ear pressure reduction for frequencies below 650 c p s, are presented as curve *a* of Fig 8 He saw advantages in this sort of action in that the system would discriminate against disturbing low frequencies, and on the basis of this it has been suggested that the middle ear does not at all act like an impedance-matching transformer, however, in this same series of experiments, Békesy made some other measurements that more accurately reflect the action of the middle ear In this instance the second measurements were made with the drum membrane and outer ossicles removed but with the stapes left in the oval window and with the round window membrane intact

When the values of volume displacement for the intact ear are divided by those for the above conditions we have a curve, *b* in Fig 8, that is in better accord with the earlier results and testifies to a useful transformer action of the middle ear for all frequencies

It is obvious from these determinations, and those showing the contribution of the middle ear to sensitivity, that the advantages are not the same for all frequencies The middle ear is not a truly high-fidelity device, but it does remarkably well Three forms of distortion, found in all forced-to-not be very accurate because of the difficulty of determining accurately from an optical lever the excursion of a vibration when the axis of rotation of the mirrors is not known, nevertheless, the figures are close enough to indicate that the principles described are the right ones

Measurements of the transformer ratio, which have been made on human cadaver material, show that these figures are fairly accurate Bekésy[1] drained out the fluid of the inner ear, dissected away the cochlea, and then applied sound to the inner surface of the stapedial footplate This he adjusted in intensity and phase so as to cancel the effects of another sound of the same frequency introduced at the drum membrane A capacitative probe near the surface of the stapes showed when cancellation was complete From these he obtained a transformer ratio of 10 at 100 c p s, rising to 18 at 2200 c p s and then rapidly falling This is shown in Fig 7 Now the lever ratio and areal ratio of the middle ear will not change with frequency, so the variations in the transformer ratio can probably be attributed to the influence of the inherent response properties of the ossicular chain

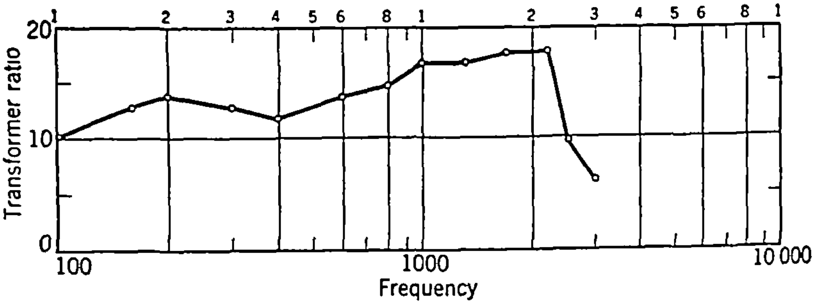

Fig 7 The transformer ratio of the human (cadaver) ear according to Bekesy[1] From Reference 10

At this point we must mention some other interpretations made on the basis of another experiment reported by Békésy in 1942[2] In this instance he measured, also on cadaver specimens, the volume displacement of the round window for a number of conditions In the first of these he cancelled out a tone applied to the inner ear through the intact middle-ear

Fig 9 shows the phase shift introduced for frequencies from 100 to 10000 c p s by the entire middle ear Positive values indicate a phase lag introduced by the ossicular chain The amount of phase variation is quite moderate for frequencies below 5000 c p s , and then grows greater and more variable for the higher frequencies Actually these phase changes remain constant at the different frequencies and so, of course, make no noticeable difference to hearing Since the sound being transmitted by this route to the oval window is more intense by about 30 db than that reaching the round window, any inner-ear effects due to the phase difference are negligible When the middle ear is removed, however, so that this advantage is lost, any phase shift in one window relative to the other makes a great deal of difference, as was described earlier

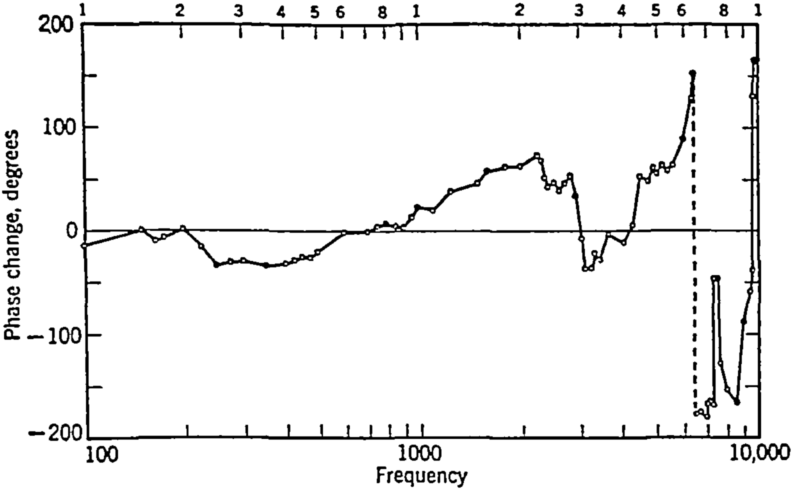

Fig 9 Phase changes produced by the entire middle-ear apparatus Positive degrees represent a retardation of phase. From Reference 10

Measurements made of phase changes attributed to action of the stapes are shown in Fig 10 These variations are small, never exceeding 15 degrees below 5000 c p s , but as shown in Fig 5 it takes very little shift from the cancellation point to improve the situation This demonstration of the vibrate devices, that have been extensively studied in the middle-ear response to acoustic vibrations are frequency, phase and non-linear or amplitude distortion

The first of these, frequency distortion, is illustrated in Fig 6 This curve represents the frequency response for the middle ear of the cat Like any other device, when forced to vibrate, it exerts its own resonance properties into the vibration and so alters the frequency characteristics In the human ear this middle-ear frequency distortion is reflected, along with many other hearing phenomena, in the sensitivity curve

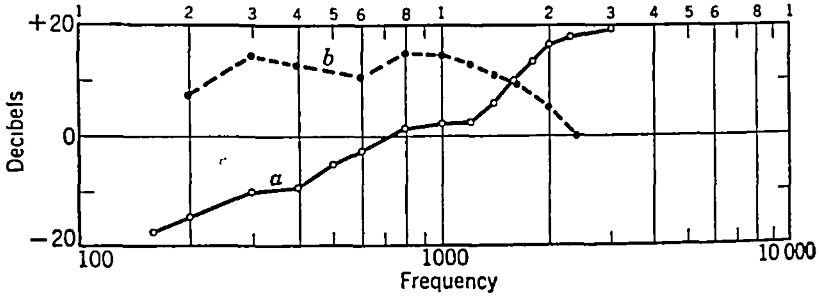

Fig 8 The pressure amplification afforded by the middle-ear mechanism as derived from the observations of Bekesy Curve *a* shows the results of Fletcher's computations and curve *b* those of Wever and Lawrence[10]

Whenever there is frequency distortion due to the characteristic mass and stiffness properties of the driven structure, phase differences are also introduced into the vibratory response This means that as the sound at the tympanic membrane reaches a positive-pressure peak or a negative-pressure peak the ossicular chain lags behind or, in fact, may appear to precede the movements of the air-borne vibration Thus the chain of middle-ear bones introduces phase distortion, not only by shifting the phase but also by doing it differently and in varying amounts over the frequency range

By employing a stimulating system similar to that described for studying the effects of different phase relations at the oval and round windows we can find out how much the middle ear shifts the phase for various stimulating tones

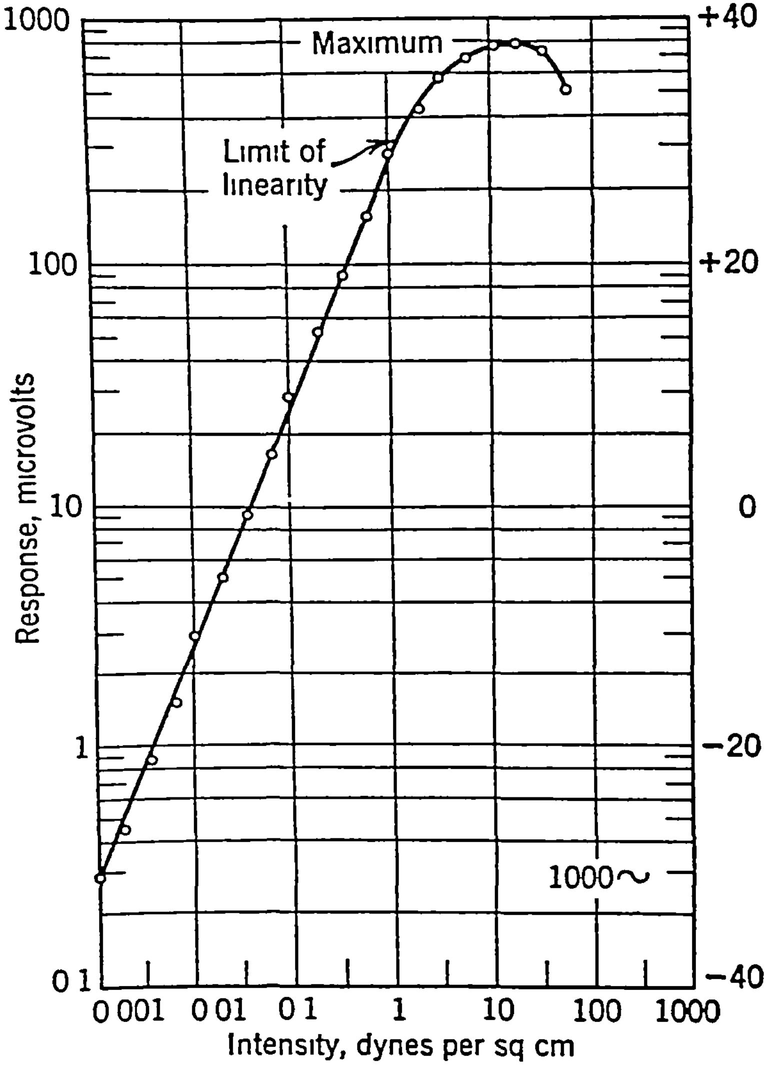

Fig 11 The intensity function for the cochlear response recorded from the round window of the cat. The limit of linearity denotes the point in the response where it is no longer proportional to changes in the stimulus intensity From Reference 10

vibration is transformed into the recorded electrical response We would like to know then, what structure or process brings on this departure from linearity and specifically, for our discussion here, we would like to know whether the conduction process in the middle ear is responsible for this phase characteristics of the stapes serves to emphasize the importance of establishing a favorable phase relationship between the two windows during any reconstructive surgery of the middle ear performed for the purpose of improving the hearing

The third type of distortion concerns the ability of the structures to follow increases in amplitude of the driving vibration A characteristic of the electrical response of the cochlea in response to a pure tone is that as the sound amplitude is increased the electrical output increases proportionally over a characteristic range, and then departs from this straight-line function until finally it reaches a maximum The point at which the response becomes no longer proportional to the amplitude increases of the stimulating sound is called the "limit of linearity," and the point at which there are no increases in response to further increases of stimulus is called the "maximum," as shown in Fig 11 The electrical response recorded in this instance reflects not only the transmission of sound through the middle ear and through the fluids of the inner ear, but also the process by which this

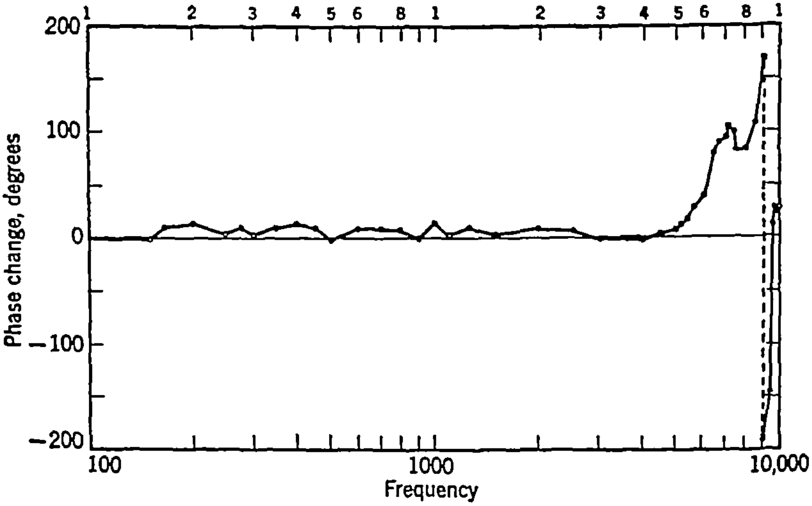

Fig 10 Phase changes produced by the stapes Positive degrees represent a phase lag in the oval-window pathway relative to the round-window pathway From Reference 10

The evidence gathered over the last few years has shown conclusively that the inner ear is responisble for this early departure from a linear response One way to study this is to record the magnitude of the electrical response as well as its wave shape, and compare this to the wave shape of the stimulating sound and that of the sound after it has been relayed by the ossicular chain to the fluids of the inner ear and escapes from the round window A comparison is made in Fig 12 The wave shape of the sound coming from the round window is still undistorted to a level of stimulating sound that has brought about severe wave form distortion in the electrical response If distortion had occurred in the middle ear this would have been transmitted through the fluids to the round window

Another test for the locus of this amplitude distortion has been made by applying a vibrator, first to the umbo of the malleus then to the head of the stapes, and recording the cochlear response in both instances If the middle ear is responsible for this type of distortion, departure from linearity should occur at a lower response level when the middle ear is present than when it is removed Results are shown in Fig 13 The limit of linearity occurs at the same response level for both methods of stimulation, indicating that the middle ear is not responsible Since the middle-ear lever, which reduces stapes amplitude while increasing pressure is removed in one instance, the response through the stapes alone is greater for equal sound pressures than the response after traversing the ossicular chain

It is true that if the middle ear is driven hard enough it, too, will become non-linear but not until a level of sound has been reached that would have destroyed the inner ear, and nothing seems to affect this ability of the middle ear to respond linearly over a considerable range of sound intensities The middle ear can be filled with fluid or the stapes ankylosed and, although sensitivity is lost, the middle-ear dynamic range is very little affected

In the process of conducting sound from the external meatus to the fluids of the inner ear the tympanic membrane and ossicular chain do not only an amazingly efficient job of

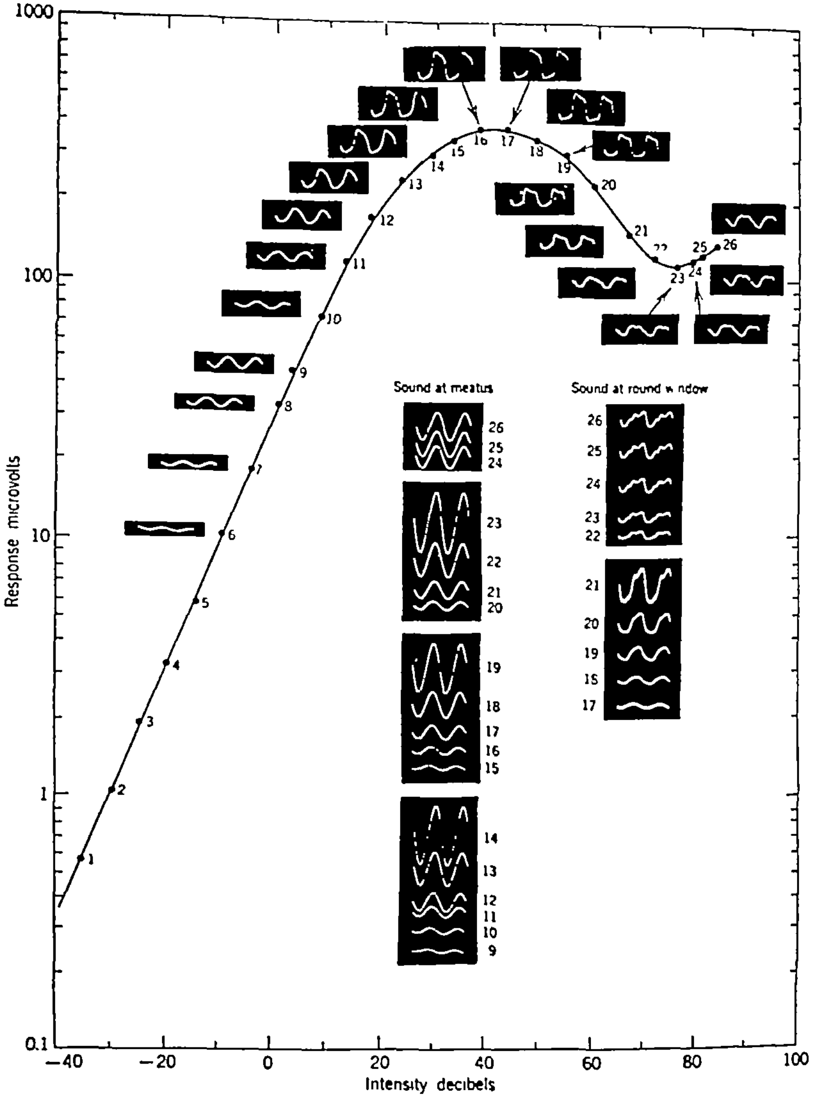

Fig 12 The intensity function for the cochlear responses of the cat s ear with a display of wave forms of this response at different levels The intensity scale is in decibels relative to 1 dyne/cm (74 db above 0002 dyne/cm) The points of measurement along the curve are numbered and from 6 on each has adjacent to it an oscillogram of the cochlear response obtained For these waves the amplification of the oscillograph was constant up to point 9 and then was reduced and held constant thereafter for points 10 to 26 In two columns below are oscillograms for some of the sounds entering the ear at the meatus and also for sounds picked up from the round window In recording these sounds the amplification of the oscillograph was constant for each block of pictures but was varied between blocks From Reference 10

matching the properties of air to those of the dense perilymph so as to introduce sound with a minimum of loss, but do so over a wide range of frequencies with no amplitude distortion within the range of inner-ear response and with tolerable frequency and phase distortion

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DISCUSSION OF DR LAWRENCE'S PAPER ON "PROCESS OF SOUND CONDUCTION"

Henning E von Gierke *

The starting point for any serious discussion is a point of disagreement, of doubt, or a question mark It would be very hard to pick out such a point from Dr Lawrence's excellent presentation I think it became quite clear from his

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*Aero Medical Laboratory Wright Air Development Center Wright-Patterson Air Force Base Ohio

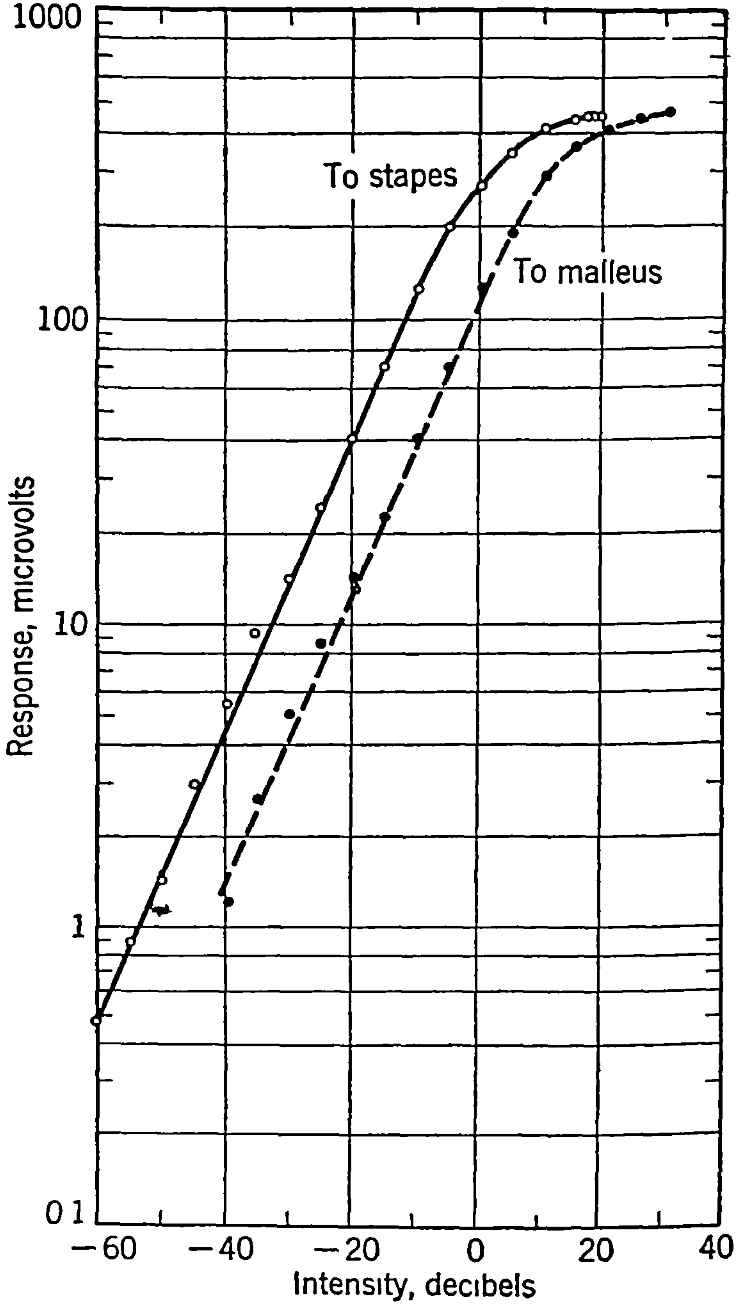

Fig 13 The cochlear response recorded from the round window in response to mechanical vibration at a frequency of 1000 c p s of the stapes and the malleus The limit of linearity occurs at the same response level in both instances From Reference 10

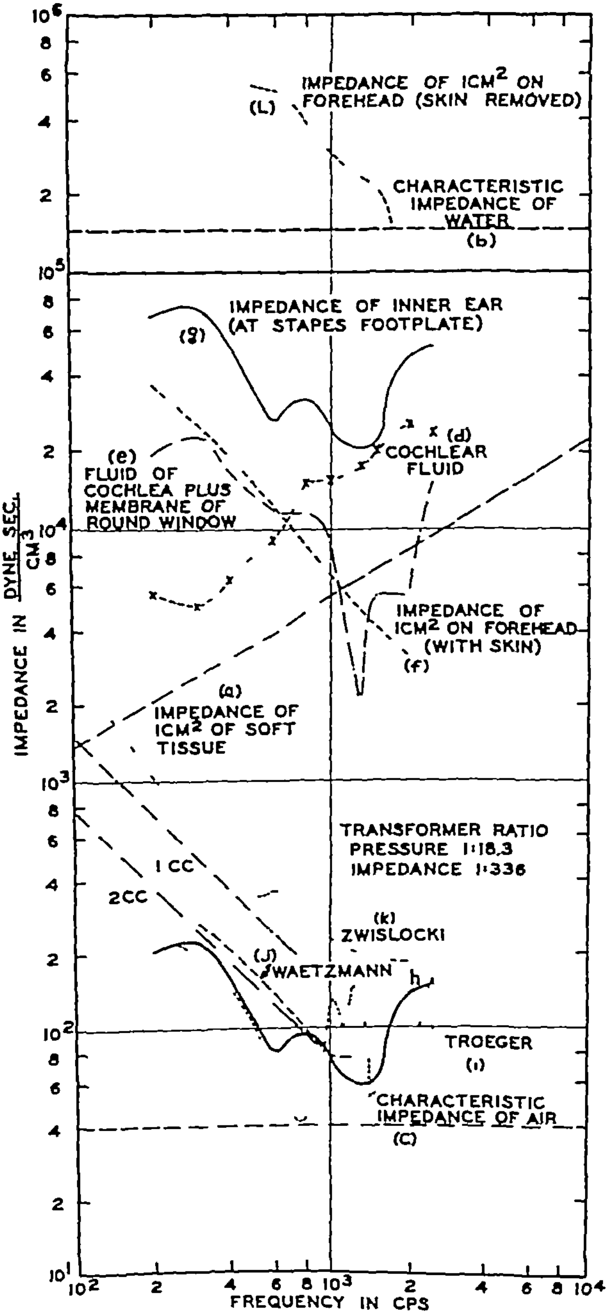

Fig. 1 Impedance Values Measured at Various Locations in the Ear and on the Body Surface—a Impedance of area (1 cm²) overlaying soft tissue (upper arm), b characteristic impedance of water c characteristic impedance of air, d Impedance of cochlear fluid e Impedance of cochlear fluid plus membrane of round window f Impedance (area 1 cm²) of the forehead (with skin) g Impedance of the inner ear measured at the footplate of the stapes h Inner ear impedance as appearing at the tympanic membrane (curve g transformed by the middle ear) i-j-k impedance values measured at the tympanic membrane l impedance measured on the forehead without skin (area 1 cm²)

presentation that our physical understanding of the conduction mechanism is fairly good, that we are in the position to give average quantitative numbers to the different components of the transmission system, and that in this part of the auditory mechanism the various hypotheses have been almost completely replaced by measured facts This does not mean that there is not much room left for very worthy and interesting refinement It simply means that there are no big surprises waiting to be discovered

Let me add a few words to refine our picture of the physical purpose of the middle ear Since the acoustical properties of human tissue are very close to the acoustical properties of water, a very simplified statement of the middle ear's task is that it has to match the impedance of air to the impedance of water (Under impedance we understand the ratio of the driving sound pressure to the velocity of the resulting motion, a measure of mobility Depending on the phase between pressure and velocity, the impedance can be a mass reactance, an elastic reactance or a frictional resistance, or a combination of these three elements) This impedance of water or tissue is a well known constant only if we have undisturbed sound propagation in an almost infinitely large medium This is practically never the case for sound in tissue and, therefore, the impedances of the middle and inner ear do not so much depend upon the acoustical constants of the tissue as they do upon the geometrical shape and the boundaries of the elements involved For example, a blocking of the round window with an otherwise completely intact conduction mechanism would change the impedance or mobility at the oval window considerably, and consequently also the impedance at the tympanic membrane

To illustrate this point, impedance values measured at various locations in the ear and on the body surface are shown in Fig 1, together with the impedance of an infinite water or air medium Curve *a*, represents the impedance of a small circular area (of approximately the same size as the tympanic membrane) at the surface of soft tissue, as measured over soft muscle and skin[6] It is mainly a mass reactance, increasing with frequency We see that this impedance is volume of this cavity, we measure impedances of the general shape indicated in Fig 1 by the impedances for air volumes of one and two cubic centimeters Only here in this region, where the middle ear increases the transformed inner ear impedance, the middle ear transformer does not act as an "ideal transformer "

This elasticity of the middle ear cavity, together with the elasticity of the tympanic membrane itself are the reasons why the impedance measurements at the tympanic membrane have only limited value for diagnostic purposes, not all acoustic energy received by the tympanic membrane is conducted to the labyrinth On the other hand impedance measurements are almost the only objective examination method available to make a real measurement of the sound conduction mechanism *in vivo* It is regrettable that so far this method has never been refined and improved, so that it could be clinically applied to those cases for which its usefulness has been proven in principle the diagnosis of conduction impairments[3]

On Fig 2 the absorption co-efficients resulting from the impedance values of Fig 1 are shown The absorption co-efficient indicates the percentage of the incident airborne sound energy that is absorbed by the tympanic membrane (Curves *a* *b* *c*) and conducted to the inner ear, or absorbed by soft muscle tissue (for example upper arm, Curve *d*) or bone (Curve *e*) Curve *f* indicates how little energy of a plane airborne sound wave is transmitted through a boundary between air and water It should be noted here that in many cases, as Metz[3] has shown, conduction impairments in persons having normal tympanic membranes are detectable by a decrease of the absorption co-efficient measured at the tympanic membrane

The absorption co-efficient shown in Fig 2 for bony structure, Curve *e* can hardly be used to calculate the threshold of bone conduction It gives only the energy absorbed by the surface of the forehead, and does not tell us how much this energy is attenuated in the bone on its way to the inner ear Most of this energy is already absorbed in the skin and not transmitted to the bone itself, therefore, whereas the energy absorbed at the tympanic membrane, Curves *a*, *b*, *c*, is, at considerably below the impedance for plane compressional waves in water, Curve *b*, which is so often cited as the approximate impedance of tissue to which the middle ear transformer has to match the impedance of the air, Curve *c* The reasons for the difference between Curves *a* and *b* are not so much the differences in the properties of tissue and water, but they are the boundaries of the medium and the type of wave propagation set up in it Over the whole audio-frequency range we hardly ever find compression waves in the body tissue, we always have shear waves and surface waves, which have different propagation velocity, absorption and wave length[6] I think this fact cannot be stressed enough in discussing propagation of sound waves through tissue. Let us now look at the impedance of the cochlear fluid alone, Curve *d*, as measured by von Bekesy[5] We see this impedance is quite similar to the impedance of soft tissue If we add to this fluid the elastic membrane of the round window we observe on the resulting impedance, Curve *e*, the following For the lower frequencies the elastic component determines the impedance,* and this impedance is very similar to the impedance of other bony structures of the body As an example, the impedance measured on the forehead is plotted as Curve *f*[1,2], so we see the impedance values of the cochlea are of the same order of magnitude as the impedance of other body tissues The impedance measured at the footplate of the stapes, given by Curve *g*, was obtained by von Bekésy[5] If we now multiply this impedance with the square of the pressure transformation ratio of the middle ear, as discussed by Dr Lawrence, we obtain, as the impedance at the tympanic membrane much lower values of the impedance, Curve *h* These impedance values, calculated from measurements on human cadavers, agree very nicely with the impedance measurements (Curves *i* *j*, *k*) made *in vivo* at the tympanic membrane by several investigators[4,8,9] Only at low frequencies is the impedance measured at the tympanic membrane determined by the impedance of the tympanic cavity which exceeds the transformed impedance of the inner ear, Curve *h* Depending upon the to the inner ear by bone conduction, is approximately 50 to 60 db below the air conduction threshold In Fig 3 some hearing threshold measurements are shown when the sound stimulus was exciting different areas of the body[7] The data are plotted with reference to the air conduction threshold It is remarkable how relatively little difference one observes in stimulating different areas of the body This indicates that the main loss occurs at the transition surface

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*Some of the statements made here about the phases of the impedance i e if they behave like masses or elasticities are not direct conclusions from Fig 1 but follow from the original investigations

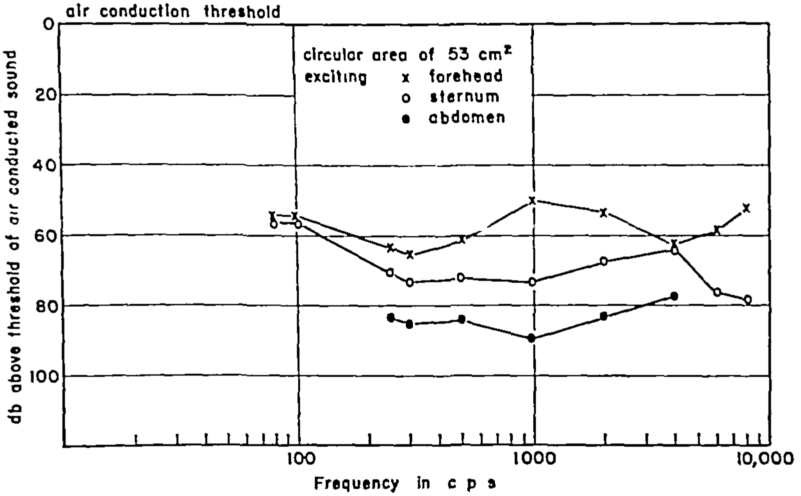

Fig 3 Threshold of hearing for airborne sound received by different areas of the body relative to the air conduction threshold

I do not want to go deeper into the problem of bone conduction here, and I think it was no accident that Dr Lawrence omitted details on it It is actually deplorable how little exact physical information we have about the bone conduction pathways in the tissue and about the details of how the bone conducted sound acts on the cochlea Since it has been shown that impedance and skull resonances, measured on skull preparations, can be related reasonably well to *in vivo* measurements, such measurements should be possible with electro-acoustic methods and tools

The physical description of the mechanical conduction mechanism is not solved until we can describe the stimulus delivered to the electro-mechanical transducers Von Bekésy's[5]

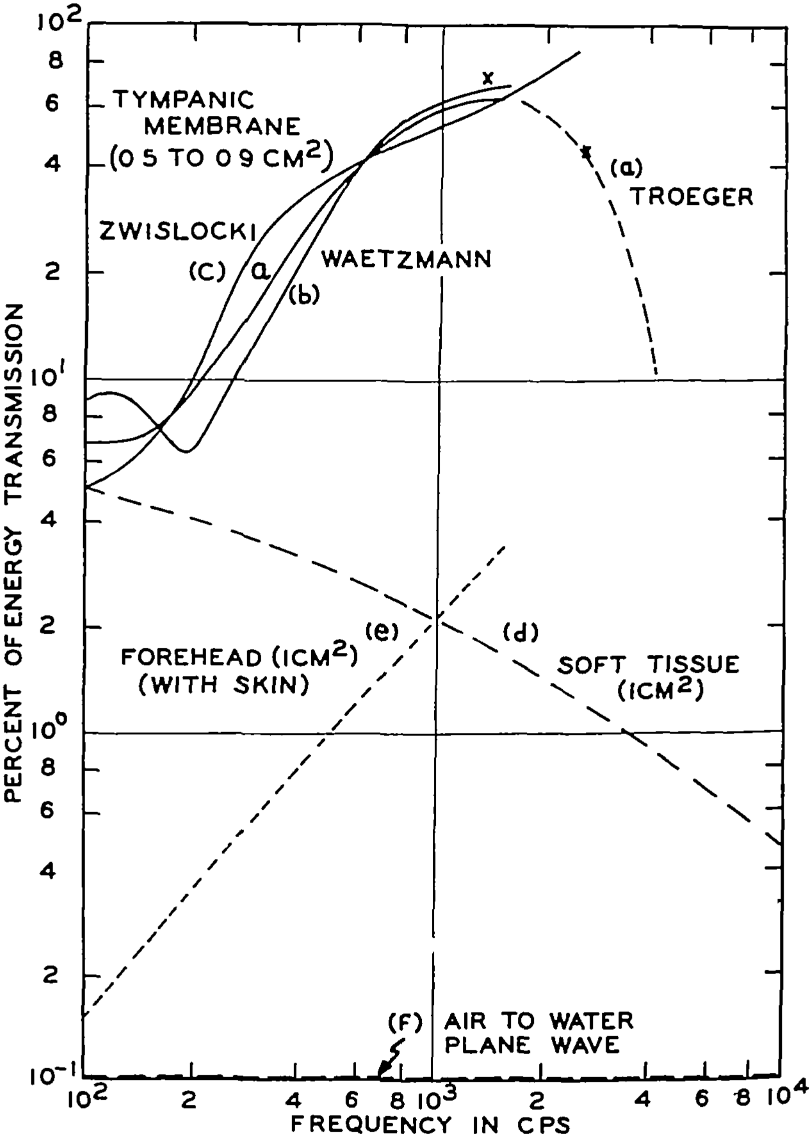

Fig 2 Acoustic energy transmission through the tympanic membrane and other human body surfaces in per cent of incident sound energy

least at the higher frequencies, almost completely transmitted to the cochlea, roughly only 1/1000 or less of the energy received by the forehead reaches the inner ear This explains why in a free sound field our threshold for airborne sound, received by body areas other than the ears and transmitted which supports the organ of Corti Any hindrance to the passage of sound waves down the external auditory meatus, across the ossicular chain of the middle ear cleft to the oval window, and finally through the labyrinthine fluids to the basilar membrane, will cause an impairment of hearing even though the organ of Corti and VIIIth nerve are normal, furthermore, the degree of deafness is a measure of the effectiveness of the block which may be such that air borne sound waves are prevented from reaching the organ of Corti

A simple plug of cerumen in the external auditory meatus, particularly if it hinders the free excursion of the tympanic membrane, deserves pride of place as the commonest cause of conductive deafness An effusion into the tympanic cavity, a vacuum within the middle ear space due to Eustachian insufficiency, or solid matter in the shape of adhesions or growth may also impede the transmission of sound, but the most effective, and next to cerumen the most common cause of conductive deafness, is found when there is an interference with the normal mechanism whereby sound waves enter and leave the labyrinth by means of the oval and round windows In the Eighteenth Century Valsalva, Morgagni and Meckel all recognized stapes ankylosis as a cause of deafness, and late in the Nineteenth Century Politzer gave it the name otosclerosis

More recently it has been appreciated that any interference with the normal phase relationship between the oval and round windows may affect the transmission of sound to the inner ear This may happen if the ear drum is perforated so that the incoming sound waves fall more or less simultaneously on the two windows, thus cancelling each other out The reason why the earlier operations for the relief of deafness due to otosclerosis by means of an opening into the lateral semi-circular canal were so rarely rewarded by success is that the operated area was closed up so that incoming sound waves fell with more or less equal and simultaneous pressure, both on the round window and on the new window in the lateral semi-circular canal

Sourdille was the first to devise an open operation so that the incoming sound waves were free to pass through the new observations, and his measurements of the mechanical constants of the cochlea, gave us the physical understanding and led to the theories describing the mechanics of the cochlea in general terms Finer, but also important, details like the location and cause of nonlinear distortions and the mechanical energy *finally* transmitted to the hair cells are still very far from a solution It looks as though a new tool must be found to obtain access to these dimensions, and this tool might well be the electrical activity of the inner ear itself Dr Lawrence's discussion of the distortion problem and the investigations we are looking forward to hearing about from Dr Davis and his co-workers, indicate that further understanding of the electrical potentials might give us the tools to make another step ahead in measuring the mechanical conduction mechanism

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SOME CLINICAL FEATURES OF SOUND CONDUCTION

TERENCE CAWTHORNE,

London, Eng

The sound conducting part of the auditory mechanism extends from the side of the head to the basilar membrane than to irreversible degenerative changes in the cochlea or VIIIth nerve

In support of this view it may be mentioned that in many of these patients with so-called "mixed deafness," the response to speech, providing that it is loud enough, is the same as in uncomplicated conductive deafness, whereas we know that in most cases of end-organ or nerve deafness the response to speech is quite different I do not believe that in advanced otosclerosis the organ of Corti or the cochlear nerve are, because of certain conventional tests, necessarily at fault The acid test in all these advanced cases is whether they are able to understand amplified speech So long as they can do this there is reason to hope that the organ of Corti will respond to any sounds that are able to reach it

Now for another aspect of the conduction of sound waves, this time within the labyrinth I refer to the Tullio phenomenon, which relies for its effect upon a vestibular response to an acoustic stimulus Tullio originally produced this effect by making an opening into the lateral semi-circular canal of pigeons, and then observing that in response to a loud sound there was a typical vestibular response of the eyes and the head

Just before the War, I made an opening into the semicircular canal of a patient with Menière's disease The stapes was free to move, and the labyrinthine structures were intact The following short extract of a film taken in 1939 shows what happened The small light attached to the earphone lights up when a sound of 80 db is on It will be noticed that on the unoperated side nothing happens when the bulb lights up, but on the operated side it is followed by a deviation of the eyes and head You may well ask, why does this not happen after every fenestration operation? The reason is that the stapes is not free to move If it were, and I have seen it in patients who were submitted to a fenestration operation for perceptive deafness when the stapes was mobile, then this distressing effect is seen—distressing because in several cases I have had to destroy the labyrinth in order to relieve the patient of troublesome vertigo window in the lateral canal, while the round window was shielded by the tympanic membrane Sourdille's multi-stage procedure was simplified and improved by Lempert, whose fenestration operation has become the standard surgical procedure for the relief of deafness due to otosclerosis Once the sound waves have entered the labyrinth they may be hindered by abnormal conditions of the fluid therein It has been suggested that the variable low tone deafness in Meniere's disease is due to the increased pressure of endolymph interfering with the proper excursion of the basilar membrane

One of the problems facing the aural surgeon when an otosclerotic patient presents himself hopefully as a candidate for fenestration, is to estimate the chances of success Obviously if the organ of Corti itself is also defective, no operation to enable sound to re-enter the labyrinth, no matter how well it is carried out, will help if the organ of hearing is incompetent In consequence surgeons have been chary of operating on any patients who exhibit any of the classical signs of perceptive deafness

Now, as the movement of the stapes footplate in the oval window in response to sound becomes more limited as the otosclerotic bone spreads, a time must surely arrive when it will move hardly at all, even in response to powerful acoustic pressures The effect of this will be to prevent the transmission of sound waves through the oval window With only one window working but little effective sound is likely to reach the end-organ of hearing, and in consequence signs of cochlear insufficiency will be added to those of defective transmission, even though the cochlear end-organ is intact and ready to respond to any sound which may be permitted to reach it Most of us have been brought up to believe that in advanced otosclerosis cochlear changes take place Stacy Guild has shown that in the temporal bones of advanced otosclerotic deafness which he examined, there were no more histological changes in the organ of Corti and VIIIth nerve than could be accounted for by age, therefore, it seems to me that we must revise our view of advanced otosclerosis and regard the profound deafness as being due to inability of sound to reach an otherwise normal organ of hearing rather

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Dr Heinrich G Kobrak, Wayne University School of Medicine, Detroit, Michigan, presented a film on sound conduction in the ear Unfortunately, due to his unexpected death a description of the film is not available

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TRANSMISSION AND TRANSDUCTION IN THE COCHLEA *

HALLOWELL DAVIS,

Central Institute for the Deaf,

St Louis, Mo

My portion of our symposium deals with the cochlea as a sense organ The domain extends from the oval window to the internal auditory meatus Dr Lawrence has told you how sound is conducted to the inner ear, and Drs Galambos, Tasaki, Neff and others will pick up the story of the nerve impulses that emerge from it

My story breaks into two major parts the first is *acoustic analysis*, the second is *neural excitation* These follow one another logically in the sequence of transmission and then transduction They also follow in the order in which they have commanded scientific interest in the past and in regard to the extent of our present knowledge and understanding Each part is primarily concerned with one of the two major dimensions of the acoustic stimulus Acoustic analysis is concerned with how information concerning *frequency* is "coded" for transmission This has been the historic and almost exclusive subject of the "auditory theory" of psychologists, but personally, as a physiologist, I am now even more interested in how, regardless of frequency, the ear can encompass its tremendous *dynamic range*, how it can respond to movements of its tympanic membrane of sub-molecular amplitudes, whether there is a biological amplifier that stands between the movements and the nerve impulses, and, if so, how it operates

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*Prepared under Contract N6onr 272 (03) between Central Institute for the Deaf and the Office of Naval Research Reproduction in whole or in part is permitted for any purpose of the United States Government.

One final word about the footplate of the stapes in otosclerosis I have tested its mobility at operation using the dissecting microscope in many cases, and I have also inspected the round window niche

In very advanced cases of otosclerosis with profound deafness, the footplate and the distal part of the crura may be literally buried in otosclerotic bone, and occasionally I have found the round window niche also to be blocked by otoscerotic bone On the other hand, in patients whose deafness is not so severe there is often some movement in the stapes, and I have been able to observe movement of the round window in response to pressure on the stapes

In the Wernher Research Unit on Deafness at King's College Hospital Dr Littler and I have been trying to measure the impedance of the stapes in otosclerosis, and this work is still in progress

Regarding the relatively new procedure called mobilization of the stapes, which has been recently re-introduced by Dr Rosen of New York, this is arousing great interest everywhere, and there is no doubt that it works in a proportion of cases My impression so far is that it is most likely to be successful when the hearing loss for pure tones does not exceed 50 db, and being such a slight procedure, it can be justifiably recommended when only one ear is affected An important point is that if it is unsuccessful it does not in any way prejudice the chance of a subsequent fenestration operation Though it is a minor operation from the patient's point of view it is far from easy, and I feel that those who practice it should also be prepared to go through with a fenestration operation subsequently, should it not succeed

New and beautiful plastic operations for the repair of perforated ear drums, and for the restoration of the ossicular chain on ears damaged by former infection, reported by Zolliver and Wullstein, are attracting much attention, also the provision of an external meatus and middle ear for children born with aplasia of the sound conduction mechanism is now an established procedure single nerve fiber The overall task of the cochlea is to match this many-channeled single-valued communication system to the single continuously-variable channel of the open air, and then to code the particular acoustic signals in terms of patterns of nerve impulses (I hope that Dr Licklider will tell you whether I have used Prof Gabor's terms "matching" and "coding" correctly, and also how modern auditory theory combines the place principle, the frequency principle, and the all-or-none principle)

Several secondary principles, or propositions of physiology and biophysics, can be added in describing cochlear actions Some are old, some are new, but all have been greatly illuminated by recent anatomical studies or physiological experiments A few of these I shall discuss with you to the extent that time permits One of these will be the complexity of the fine movements of the cochlear partition Békésy has visualized them and finds them far more complicated than we had previously assumed Likewise the electrical responses are more varied and more complex They include not only the familiar cochlear microphonic but also one and probably two DC responses to AC stimulation The ear acts as an acoustic rectifier and integrator, and the "summating potentials" are the electrical signs of this action The endolymph has a unique chemical composition, and the endolymphatic space is strongly charged electrically relative to its surrounding tissues, but we shall hear evidence tomorrow that these unusual properties are not dependent upon one another We can now see anatomical details of hair cells, nerve endings and supporting cells to a new order of magnification with the electron microscope, but the secret of their mechano-electric transducing or amplifying action is not revealed by it The innervation of the hair cells is a complicated network, with contacts of many cells to a fiber and several fibers to a cell More recently the efferent character of the bundle of Rasmussen has become clear, and Dr Galambos will tell you how it modifies the sensitivity of the auditory receptors Here, in a feed-back control from the central nervous system, is a really new principle of cochlear action

Enough of generalities and previews Let us look rapidly

Thanks to the monumental work of Prof Georg von Békesy, who should be telling you in person his half of this story, we know quite definitely the gross pattern of movement of the cochlear partition This is the now-famous traveling wave pattern, which many of you saw illustrated in Prof Bekesy's motion picture Equally well established is the proposition that the extent of the traveling wave pattern along the cochlear partition, and the position of its maximum of displacement both vary with the frequency of the sound waves Thus the cochlea does act as an acoustic analyzer The apical end of the cochlear partition is moved and its sensory nerves are stimulated only by low frequency sounds, and those at the basal end near the round window are stimulated by all sounds (of moderate strength) whether low, medium or high in frequency This is not the exclusive one-frequency-to-one-place pattern of the piano keyboard, but it is a definite *place principle* of cochlear action, and it is not a matter of speculation but of observation Békésy has seen it hundreds of times in actual cochleas and in models, and we have verified it time and again with our electrical recordings

At the same time the cochlea also operates, within limits, on the telephone or frequency principle Nerve impulses tend to group in successive volleys that reproduce the frequency of the stimulating sound waves Up to the natural limit set by the refractory period of the nerve fibers, by the variability of their latency of discharge, and by the temporal dispersion introduced by the traveling wave pattern of cochlear action, the nerve impulses carry information about frequency *directly*, according to the frequency principle Wever postulated his volley principle of firing-in-turn as an accessory to the basic frequency principle, and was proved right experimentally by Galambos and again by Tasaki They will give you some of their details of the story later

I have alluded above to a major principle of nervous transmission namely, the *nerve impulses are all-or-none* Another is that *in the nerve axons they travel in insulated channels* They are triggered by the stimulus, but their energy is provided by the fibers Their maximum sustained frequency is two to three hundred impulses per second in a brane. As a result of this variation, the stiffness ("volume elasticity") of the cochlear partition varies by a factor of at least 100 from one end to the other.

The cochlear partition has significant stiffness and also mass. Contrary to earlier opinions, it is not under tension. When cut, the edges do not retract. The movements of the partition, like those of the middle ear, are quite heavily, but not critically, damped. Because of the gradation in stiffness and mass, different parts of the basilar membrane have different resonant frequencies, but the various parts cannot move as independent resonators. The basilar membrane, and the organ of Corti on it, are continuous structures. Their elements are coupled to one another elastically and also by friction. The endolymph and the perilymph provide some of the friction.

TRAVELING WAVE PATTERN OF THE COCHLEAR PARTITION

An increase of pressure on the footplate of the stapes, caused by a sound wave, causes a wave of acoustic pressure to spread through the fluid in the cochlea with approximately the speed of acoustic transmission in water, about 1500 m/sec. Because of the small size of the cochlea, the increase in pressure is virtually simultaneous throughout. The only elastic portion of the walls of the bony labyrinth is the round window, and its membrane bulges outward and allows inward movement of the stapes. Fluid moves from oval window toward round window. The cochlear partition lies in the path of this movement, and it bulges toward the round window. If the movement is very slow, there will also be some flow through the helicotrema, but all parts of the cochlear partition do not move with equal promptness. The relatively stiff portion in the basal turn moves very nearly in phase with the driving force, but the more flexible apical portions, particularly those whose resonant frequency is lower than the frequency of the acoustic wave that is driving the partition, tend to lag behind. As the acoustic wave reverses its pressure, the portion that is "tuned" to lower frequencies tends to overshoot and continues to lag behind the driving force exerted on it by the acoustic pressure in the fluid. Thus, because of

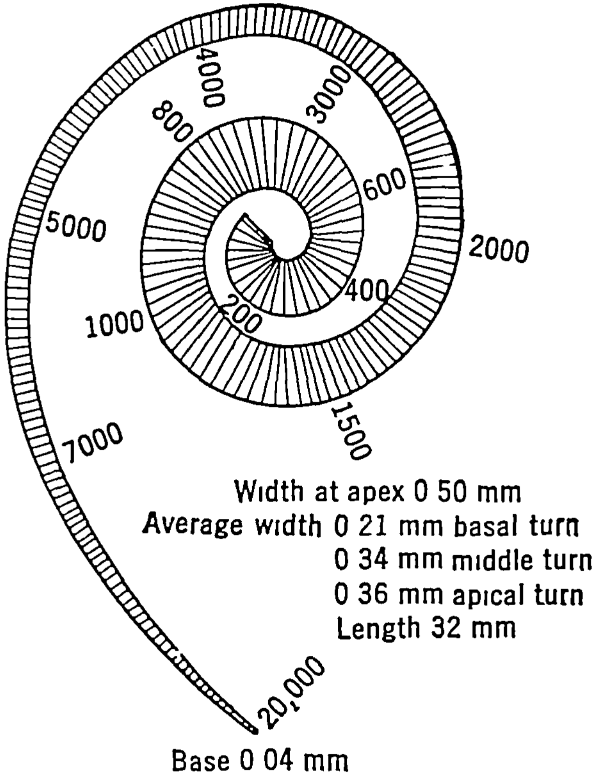

Fig. 1. Diagram of the human basilar membrane showing the approximate location of the regions of maximum amplitude of movement for tones of different frequency. The width of the membrane is exaggerated relative to its length in order to show the widening more clearly (Stuhlman).

at some of the details. We are all audiologists, so I shall not take time to review the familiar basic anatomy of the cochlea, but in Dr. Békésy's absence I shall recall briefly the story of the traveling waves, and then pass on to some of the finer details.

MECHANICAL PROPERTIES OF INNER EAR STRUCTURES

In the inner ear the basilar membrane widens gradually from 0.04 mm. at the stapes to 0.5 mm. at the helicotrema. Certain other measurements, such as cross section of the cochlear canal and relative sizes of certain types of cell in the organ of Corti, are also graded from end to end, but the important variation that allows the cochlea to act as a mechanical acoustic analyzer is in the width of the basilar mem-ing wave moves on toward the apex. The velocity of travel, therefore, diminishes, and consequently the wave length of the displacement pattern becomes shorter. A little distance beyond the position of maximum amplitude there is no significant movement at all. In the region of rapid diminution of amplitude the phase lag amounts to a full cycle or more.

If the driving frequency is increased, the position of maximum amplitude moves toward the oval window; if it is decreased the maximum moves toward the apex (see Fig. 5). At about 100 c.p.s. it is very close to the helicotrema. At 2000 c.p.s. there is very little movement beyond the mid point of the cochlear partition, but the extreme basal end of the partition moves in response to *all* frequencies within the audible range.

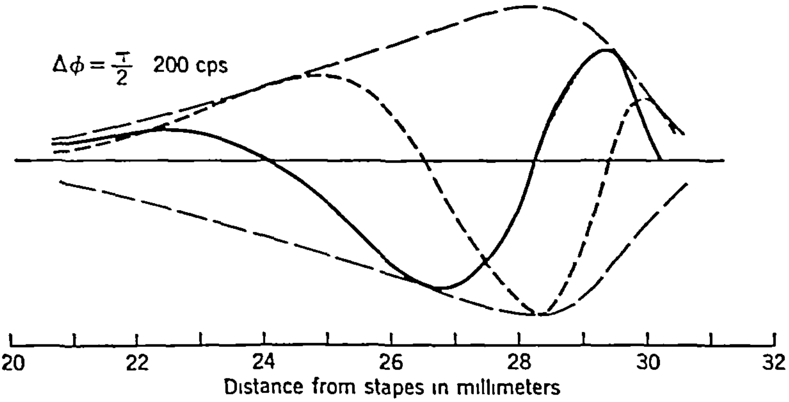

Fig. 4. Two displacement patterns are shown at an interval of a quarter of a cycle. The dashed line is the envelope of the instantaneous patterns and corresponds to the dashed curve in Fig. 5 upper. (Bekesy.)

The unsymmetrical traveling wave pattern of movement, with its rather flat maximum of amplitude and its abrupt apical reduction in activity, has been shown to be a necessary and predictable consequence of the principles of acoustic resonance in a system such as the cochlea with gradation of stiffness, mass, damping and coupling. The traveling wave pattern has been reproduced in appropriate physical models, and it has been observed directly in the cochlea under the

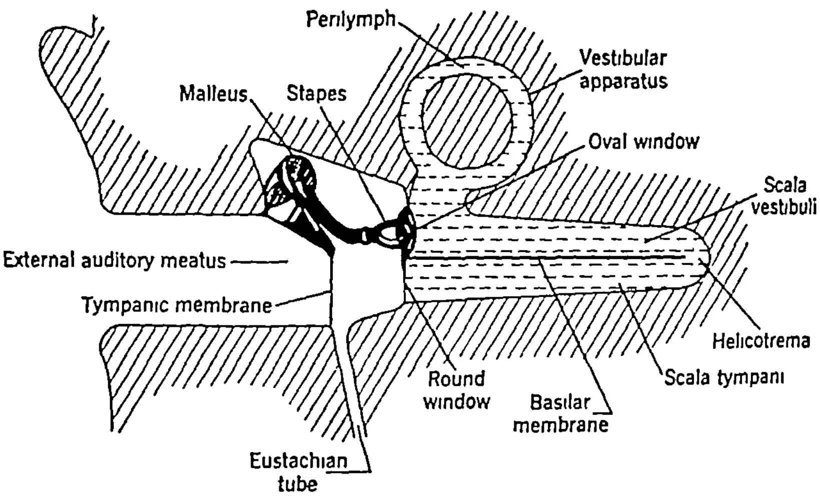

Fig 2 Overall diagram of the ear showing the ossicles in the middle ear (the incus is not labeled) and the fluid-filled inner ear The cochlea is drawn as a short straight chamber instead of a long coiled canal (Bekesy)

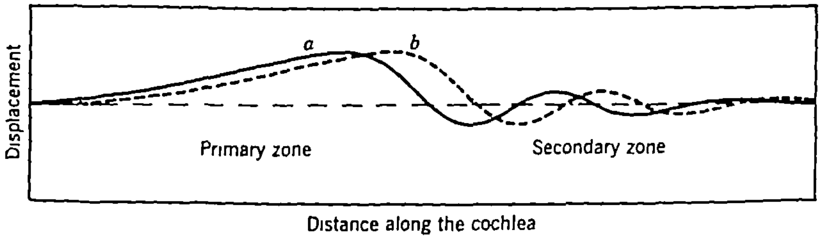

Fig 3 The solid line (a) shows the displacement pattern of the cochlear partition at one instant and the broken line (b) the pattern an instant later Actually the waves die out quite rapidly in the secondary zone and their wave length becomes progressively shorter and shorter (Wever Lawrence and Bekesy)

the gradation of stiffness, a *traveling wave* of displacement appears on the cochlear partition (see Fig 3) , furthermore, because of the continuity of the partition, the stiffer portion, moving almost as a unit, drives the more flexible portion

The traveling wave increases in amplitude as it moves apically and reaches its maximum near the region where resonant frequency of the basilar membrane corresponds to the frequency of the driving waves (see Fig 4) The amplitude of movements falls off rather rapidly beyond this point The phase lag increases more and more rapidly as the travel-of a system of diagonal fibers, and also a jelly-like substance It yields to slow movements but is quite stiff and resistant to quick movements It returns rather slowly after being detached from its normal attachment to the organ of Corti and then displaced

Apparently, as the basilar membrane bulges "upward" or "downward" (see Fig 7), the stiff reticular lamina tends to rock, on the support of the rods of Corti, around an axis at the attachment of the basilar membrane to the bony modiolus The tectorial membrane swings on its attachment to the limbus The result is a shearing action between the tectorial membrane and the reticular lamina (see Fig 8) The "hairs" arise from the cuticular plates of the hair cells, which are set firmly in the reticular lamina, and their outer ends are firmly imbedded in the tectorial membrane, therefore, as the basilar membrane bulges, the hairs are bent The force of the move-

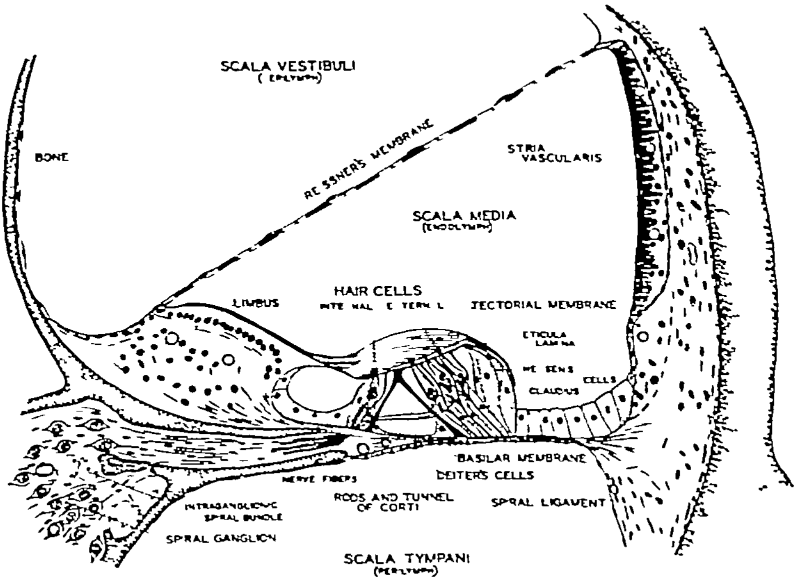

Fig 6 Camera lucida drawing of a cross section of the cochlear partition in the second turn of a guinea pig cochlea The attachment shown here of the tectorial membrane to the inner supporting cell and to Hensen s cells is based on microdissection of fresh unfixed specimens

microscope with stroboscopic illumination It allows the cochlea to act as a mechanical frequency analyzer, because the extent of activity and position of maxima vary as functions of frequency It introduces additional features, such as asymmetry, progressive time and phase lag, and significant longitudinal as well as transverse bending of the cochlear partition, that contribute to the pattern of neural excitation that results from the movements of the partition

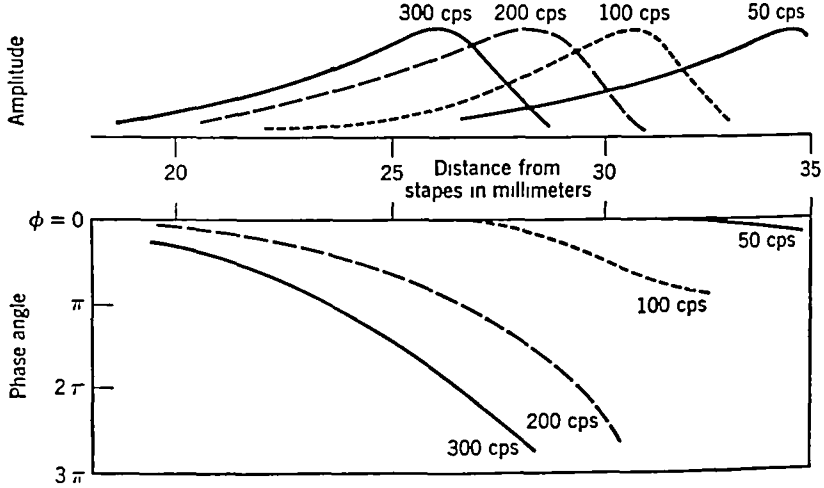

Fig 5 The upper set of curves shows the amplitude of displacement of the cochlear partition at various distances from the stapes and for several driving frequencies The lower set of curves shows the corresponding phase angles (Bekesy)

THE FINE MOVEMENTS OF THE ORGAN OF CORTI

The fine movements of the organ of Corti and the tectorial membrane have been observed under the microscope by stroboscopic illumination and described in some detail by Békésy In any one segment the basilar membrane, organ of Corti, tectorial membrane, and usually Reissner's membrane also, move in phase with one another The basilar membrane is fibrous and elastic, and basically it determines the traveling wave pattern of vibration described above The cells of Hensen form a soft cushion supporting the stiffer plate of the reticular lamina The tectorial membrane is hinged like the cover of a book along the edge of the limbus It is composed and the hairs are presumably bent longitudinally instead of radially (see Fig 9)

The exact significance of these different directions of movement in relation to the excitation of nerve impulses by the hair cells is still a matter of speculation, but the bending of the hairs is the final and critical mechanical event that has been recognized in the mechanism of stimulation At this point the significant events apparently become electrical, for this bending of the hairs seems to release energy in the form of bioelectric potentials, and these potentials are in all probability an important intermediate step in the mechanism of excitation of the auditory nerve fibers

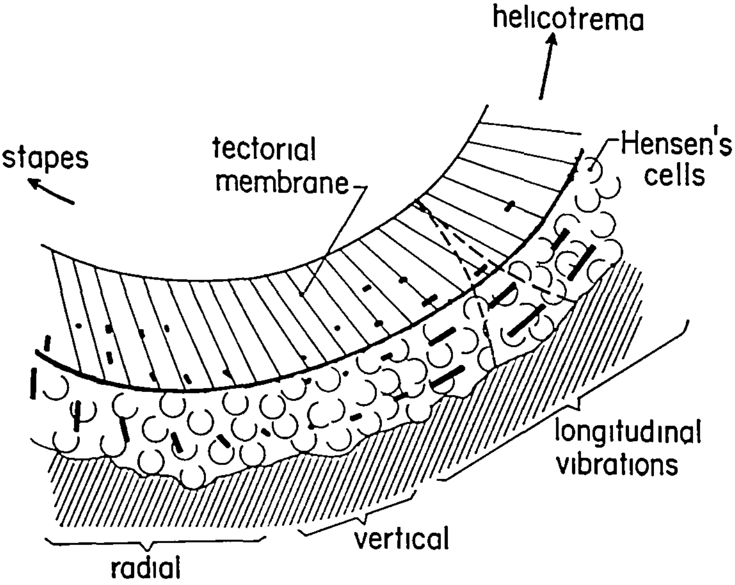

Fig 9 Movements in the cochlear partition viewed from the upper edge of the stria vascularis The greatest amplitude of displacement in the pattern shown in Fig 6 is in the region here labeled vertical (Bekesy)

The *endolymph,* which fills scala media, differs sharply from perilymph in its ionic content Unlike all other body fluids, it is high in potassium and low in sodium It more nearly resembles intra-cellular fluid in this respect Typical

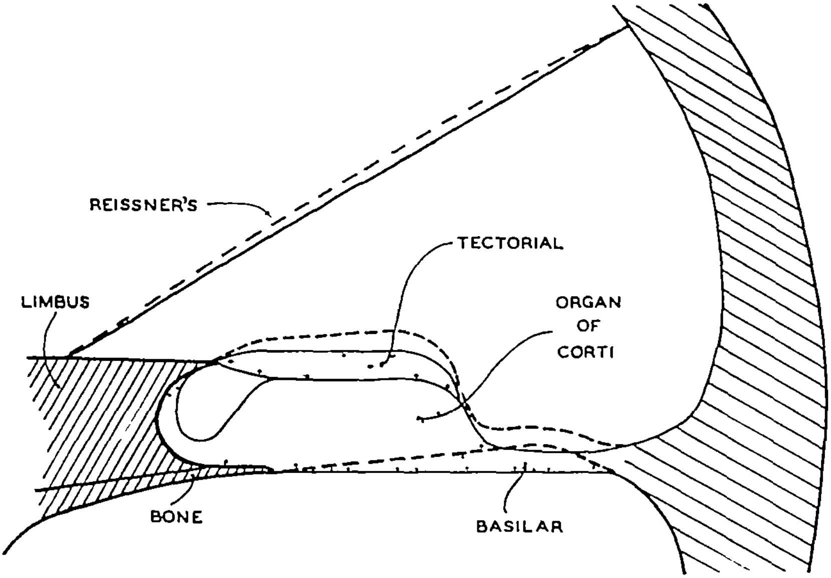

Fig 7 Probable pattern of displacement of the cochlear partition seen in cross section

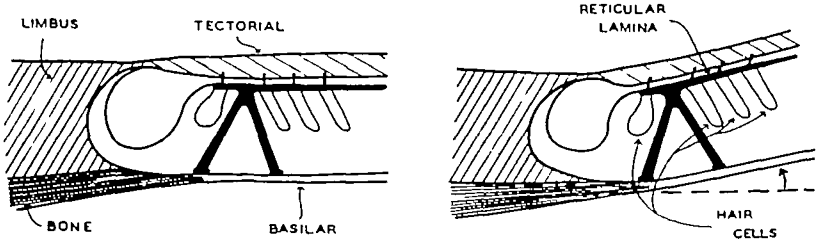

Fig 8 Probable pattern of shearing action between tectorial membrane and reticular lamina with bending of the hairs

ments of the cochlear partition is rather efficiently concentrated on the shearing action

The movement described above is associated with an approximately *radial* displacement of Hensen's cells, as seen under the microscope, and a corresponding radial or slightly diagonal bending of the hairs This movement is characteristic on the basal side of the position of maximal amplitude On the apical side, however, due to the shorter wave length of the traveling wave and sharper longitudinal bending of the basilar membrane, a *longitudinal* movement predominates,

THE ENDOCOCHLEAR POTENTIAL

The interior of scala media, the endolymph, is electrically *positive* relative to the perilymph in scala vestibuli and scala tympani and to the spiral ligament and extra-cochlear tissues in general This potential is +80 mv It is encountered abruptly at the point where the exploring electrode enters the endolymphatic space The change of potential in going from the interior of a hair cell through its cuticular layer into scala media is thus about 150 mv

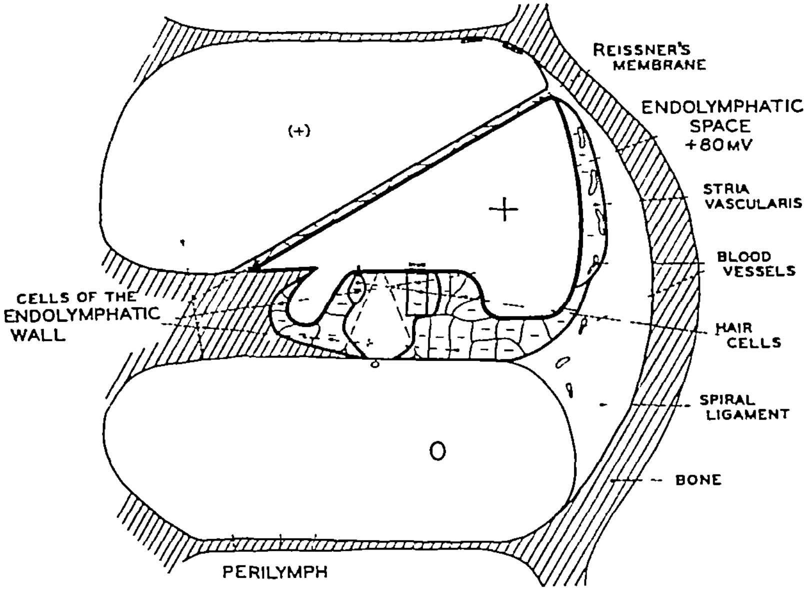

Fig 11 The endolymphatic space bounded by the heavy line carries a positive electrical charge of 80 mv relative to the perilymph in scala tympani Scala vestibuli is not more than 5 mv positive The interiors of all of the cells of the cochlear partition are electrically negative

The endocochlear potential is closely dependent on an adequate oxygen supply It falls, reversibly, to a very low level at the stage of asphyxia that is reached in extreme Cheyne-Stokes respiration (in anesthetized, moribund guinea pigs) Full recovery requires only a few seconds after a large single gasping inspiration It is also abolished rapidly by injection of cyanide or azide into scala tympani or scala media It is analyses of endolymph, perilymph and cerebro-spinal fluid are given in Fig 10 The endolymph has sometimes been described as "viscous," but this is probably true only for certain fish and perhaps other lower forms

The endolymph is probably secreted by the stria vascularis Whether it is also reabsorbed wholly or only in part by the same structure is a matter of debate

	Spinal Fluid	Perilymph	Endolymph
	millieqivalents per liter		
Potassium	4 2	4 8	144 4
Sodium	152 0	150 3	15 8
Chloride	122 4	121 5	107 1
	milligrams per cent		
Protein	21 0	50 0	15 0

Fig 10

INTRACELLULAR POTENTIALS

Nearly all cells show a negative intracellular potential Explorations of the cochlea and the auditory nerve with very fine microelectrodes reveal these intracellular potentials, ranging from -60 or even -80 mv relative to the potential of the perilymph in large cells, such as Hensen's or Claudius' down to -20 mv or so in the cells of Reissner's membrane The exact value seems to be a function of the amount of injury caused by the microelectrode, the greater the injury the lower the value The hair cells, like the nerve fibers and supporting cells, are electrically *negative* internally signal, but to a root-mean-square value, integrated over a very short time Thus the summating potentials reproduce approximately the form of the *envelope* of the original acoustic signal The positive and the negative summating potentials are opposite in sign They can be separated by the greater vulnerability of the positive summating potential to oxygen lack and other injury, and by the more apical site of generation of the negative response The input-output relations of the summating potentials are now being investigated They are not simple

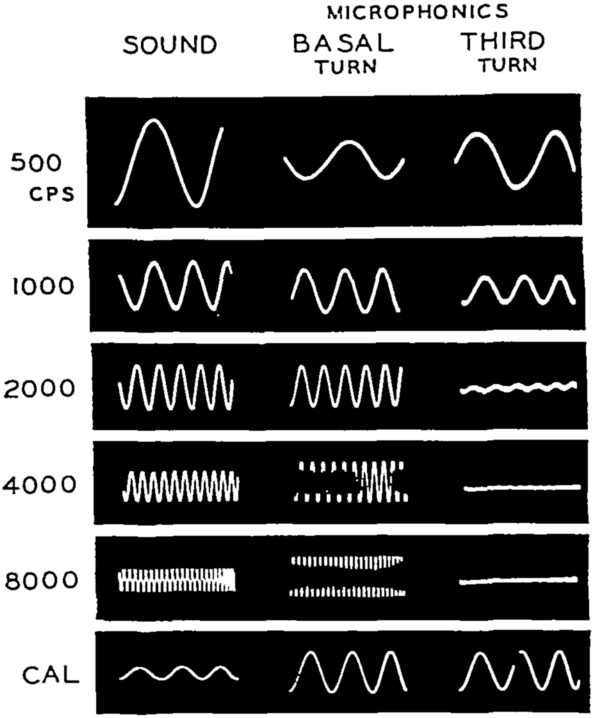

Fig 12 The cochlear microphonic recorded by intracochlear electrodes on opposite sides of the cochlear partition reproduces the sine wave form of a pure tone The basal turn responds to all frequencies but the third turn responds only to frequencies below about 3000 c.p s

The cochlear microphonic is generated at the cuticular surface of the hair cells This is clearly proved by exploration not immediately affected by injection of isotonic potassium chloride, choline chloride, or potassium glutamate into scala tympani or scala vestibuli It does fail, although less rapidly than with cyanide, following surgical injury to scala media or the injection into scala media of a solution that differs substantially in ionic content from the analytic figures for endolymph given in Fig 10

The endocochlear potential is modified by displacement of structures within the cochlear partition Displacement of the basilar membrane toward scala tympani, as by injection of fluid into scala media or an inward movement of the stapes, causes an increase in the positive potential by as much as 5 or 10 mv Movement in the opposite direction, as by outward movement of the stapes, causes even greater reductions in the potential Movements of Reissner's membrane alone are not effective, but movements of tectorial membrane relative to the reticular lamina, when it is manipulated by a microneedle, produce just such changes in potential The changes are related to displacement, not to velocity, and are sustained as long as the displacement is maintained

The *source* of the endocochlear potential has not been identified, although both hair cells and the stria vascularis have been suggested The *changes* in endocochlear potential, described above, are clearly associated with the organ of Corti, almost surely the hair cells, but it is not certain that the resting positive endocochlear potential is generated here Perhaps a separate electric response to mechanical stimulation occurs in the hair cells and simply adds to the background potential that is produced by another "generator"

THE COCHLEAR MICROPHONIC AND THE SUMMATING POTENTIALS

The cochlear microphonic and two summating potentials (positive and negative) are all electric responses to acoustic stimulation The cochlear microphonic is linearly proportional, up to a limit, to the displacement of the cochlear partition and thus, indirectly, to the instantaneous acoustic pressure The microphonic thus reproduces the *wave form* of the acoustic stimulus (see Fig 12) The summating potentials are proportional, not to any instantaneous value of the acoustic signal, but to a root-mean-square value, integrated over a very short time Thus the summating potentials reproduce approximately the form of the *envelope* of the original acoustic signal The positive and the negative summating potentials are opposite in sign They can be separated by the greater vulnerability of the positive summating potential to oxygen

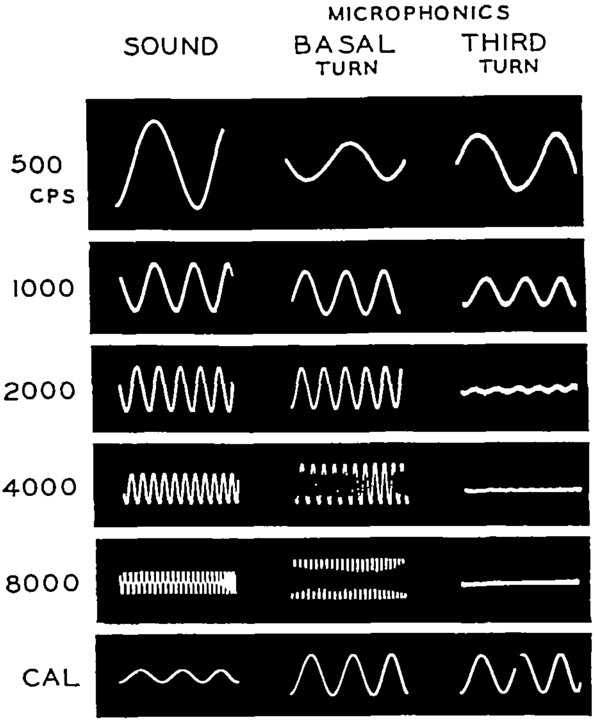

Fig 12 The cochlear microphonic recorded by intracochlear electrodes on opposite sides of the cochlear partition reproduces the sine wave form of a pure tone The basal turn responds to all frequencies but the third turn responds only to frequencies below about 3000 c.p s

lack and other injury, and by the more apical site of generation of the negative response The input-output relations of the summating potentials are now being investigated They are not simple

The cochlear microphonic is generated at the cuticular surface of the hair cells This is clearly proved by exploration with microelectrodes The microphonic, and in all probability the summating potentials also, seem to reflect the bending of hairs in the appropriate direction Apparently at intensities high enough to evoke the summating potentials, some kind of mechanical rectifying or detector action takes place in the inner ear to cause an unsymmetrical, persistent one-way bend in the hairs of certain cells In some cases the bending is probably across, in others lengthwise of the organ of Corti (A theory that includes this and several other aspects of the electrophysiology of the cochlea has recently been published in *Physiological Reviews,* 1957)

Both the cochlear microphonic and the summating potentials are continuously graded responses, linearly related within limits, to the intensity of the acoustic stimulus, and with no true "threshold" like that of all-or-none action potentials No evidence of any all-or-none response in the sensory cells or of a refractory period has been found, even when the cochlear microphonic was recorded from an electrode inside a hair cell Both the microphonic and the summating potentials show very little or no fatigue or adaptation

The cochlear microphonic "appears," in the sense that it reaches an rms value of a microvolt or thereabouts, at a much lower sound pressure level than the summating potential, except at the extreme high-frequency limit of response In the basal turn in the guinea pig the increase is linear, with the sound pressure level up to about 80 db relative to 0 0002 microbar The response then increases more slowly and usually goes through a maximum At low frequencies ordinary mechanical non-linear distortion limits the output At higher frequencies the electrical output is limited, but the wave form of the cochlear microphonic is well maintained, with little or no "peak-clipping," in contrast to the flat-topped waves seen at lower frequencies The summating potentials "appear" some 20 db above the cochlear microphonic, and continue to increase up to limits set only by acoustic trauma to the organ of Corti

The cochlear microphonic, like the endocochlear potential, is closely dependent on an adequate oxygen supply Later we shall hear evidence that the cochlear microphonic is not entirely dependent on the positive potential of the endolymph The cochlear microphonic, however, apparently does represent, as Békesy originally implied, an amplifier action in which the acoustic stimulus "valves" the energy from a preexisting "biological pool," such as the endocochlear potential

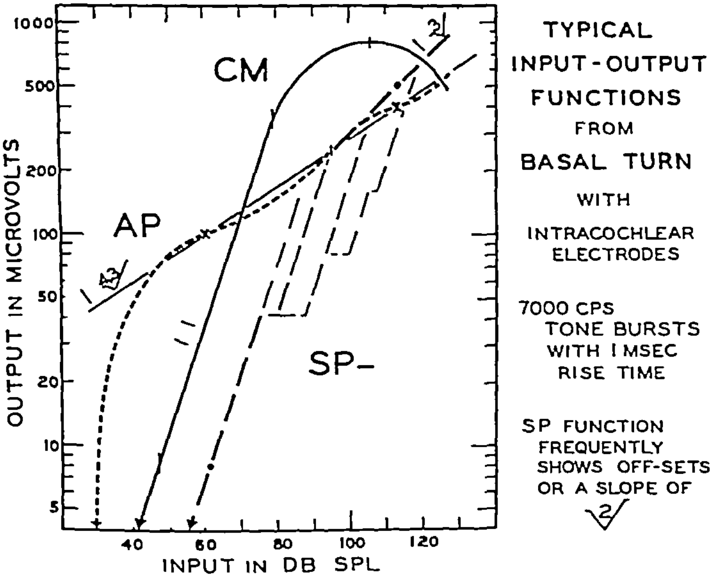

Fig 13 The voltage of the cochlear microphonic is proportional to the sound pressure level up to about 80 db SPL but goes through a maximum at about 105 db SPL The height of the action potential spike (N_1) increases rapidly from threshold and then gradually at a rate that varies between the third and the fifth root of the sound pressure level The negative summating potential is directly proportional to sound pressure level when it first appears It does not show a maximum like CM, but its increase is often interrupted by plateaus No single typical curve can yet be drawn for SP

We may add that the negative intracellular polarization is also such a "pool" In any case it now seems clear that the sustained changes in the endocochlear potential noted above certainly represent a modulation of a biological source of energy, and not simply a passive physical transducer mechanism

The summating potential, as usually seen, is a displacement of the baseline of the oscilloscopic record on which the cochlear with microelectrodes The microphonic, and in all probability the summating potentials also, seem to reflect the bending of hairs in the appropriate direction Apparently at intensities high enough to evoke the summating potentials, some kind of mechanical rectifying or detector action takes place in the inner ear to cause an unsymmetrical, persistent one-way bend in the hairs of certain cells In some cases the bending is probably across, in others lengthwise of the organ of Corti (A theory that includes this and several other aspects of the electrophysiology of the cochlea has recently been published in *Physiological Reviews*, 1957)

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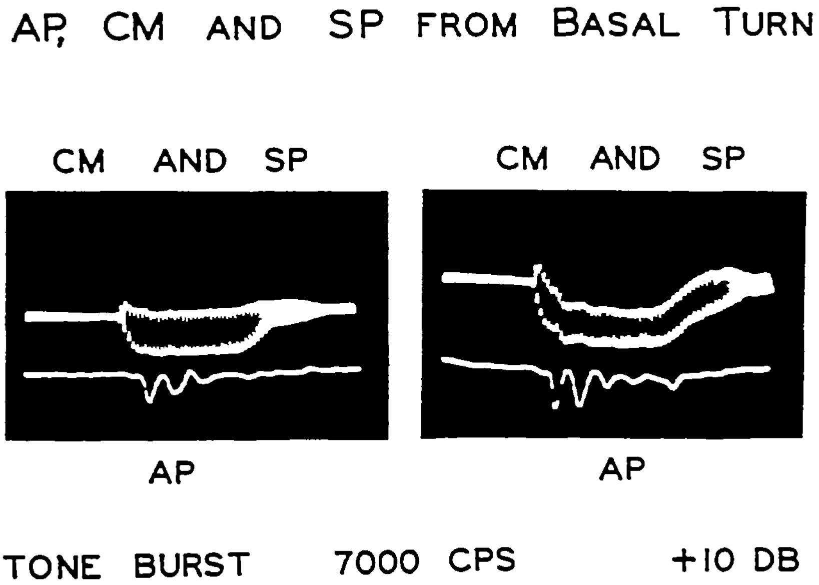

Fig. 15. The AP response can be separated from CM and SP by using intracochlear electrodes, an appropriate input network and two recording channels. The stimulus for the responses at the right was 10 db stronger than for those on the left. Note that AP and SP- have increased while CM has decreased slightly.

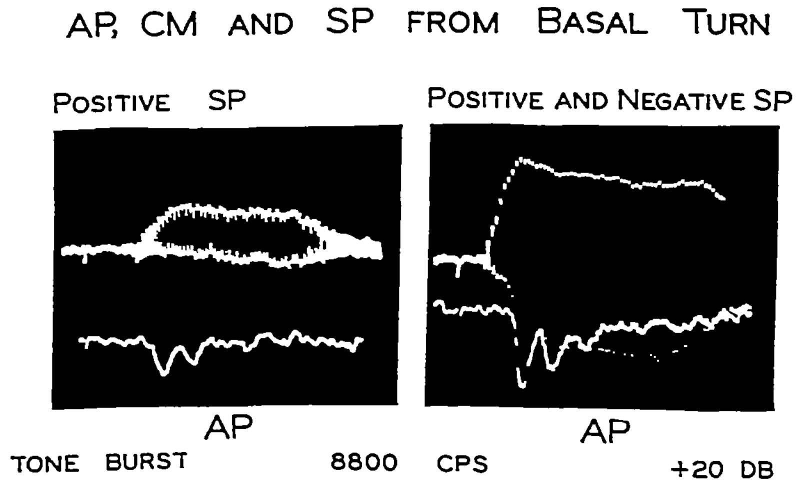

Fig. 16. In some preparations with weak stimuli the SP response is dominantly positive. A stronger stimulus gives a composite SP response.

microphonic is superimposed It is a paradoxical fact that, with mild anoxia, abnormal ionic concentrations, etc, while the cochlear microphonic diminishes the negative summating potential increases The diphasic effect of anoxia, etc, is best explained by assuming that, *1* there is a positive as well as a negative summating potential, generated by a different set of sensory cells, and that *2* the positive response is more sensitive to anoxia than the negative The negative summating potential seems to be stronger, although higher in threshold, and only under more severe anoxia or ionic injury does it in its turn weaken and finally disappear

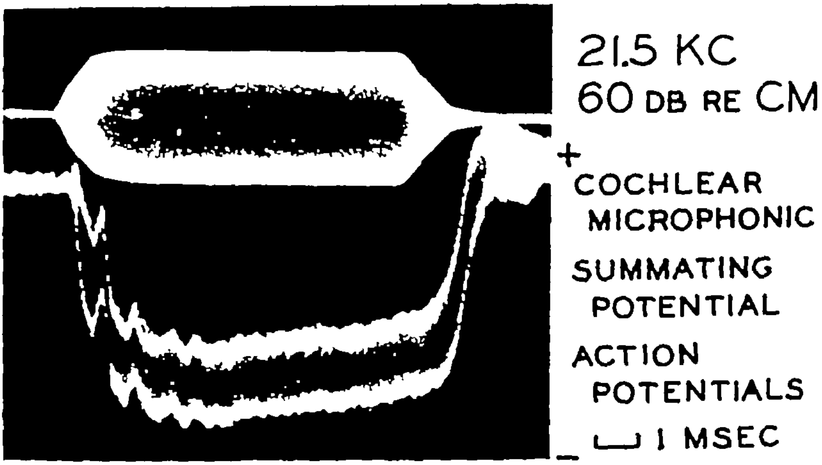

Fig 14 The upper trace is the electrical pattern of a tone burst at 21 5 kc An electrode on the round window of guinea pig records a complex electrical response consisting of cochlear microphonic (at the frequency of the sound waves) summating potential (downward displacement of the base line) and action potentials (the peaks and notches on the descending limb of the SP response) The stimulus is maximal for CM. Its sound pressure level is 60 db above the level needed for a CM response of 3 μv The apparent decay of SP during the tone burst is an artifact due to the condenser coupling of the recording amplifier After the end of the tone burst the CM response to the reverberation continues to be nearly maximal

We shall rely on Drs Galambos and Tasaki to provide further details concerning the nerve action potentials in the second order and first order auditory neurons respectively Let us devote the remaining moments to a quick interpretive summary of some of our statements about cochlear mechanics, is strongest on the apical side of the position of maximum excursion The sustained bend of the hairs presumably acts as a steady stimulus to the hair cells that are affected, but compared to the alternating shearing movements revealed by the cochlear microphonic this mechanism is relatively insensitive The rectifying action, as revealed by the negative summating potential, continues to increase, however, after the vibratory movements, and with them the cochlear microphonic, have reached their maximum The rectifying action, however it is produced, seems to be a mechanism that significantly extends the dynamic range of the ear

The complete theory, as presented elsewhere, considers the mechanism of limitation of crosswise bending (and with it the cochlear microphonic) in more detail and it also includes a second rectifying action, associated with the crosswise bending, that depends on the viscous properties of the tectorial membrane This second mechanical rectifying action and consequent one-way bias of the hairs is invoked as the basis of the positive summating potential, but this extension of the theory, as well as a possible inhibitory action of the positive summating potential, is admittedly more speculative than the postulate of the longitudinal "shift" and its production of the negative summating potential

The association of the cochlear microphonic with the bending of the hairs seems very well established The mechanism that connects the two is completely obscure, however A vague suggestion that the mechanical distortion changes the electrical resistance of the upper ends of the hair cells has been offered but without supporting evidence Whatever the mechanism, the bending of the hairs is supposed to account for not only the cochlear microphonic but also both of the summating potentials, but these three electrical responses, it should be noted, are observed phenomena, not theories

Consideration of the extreme sensitivity of the ear, and also the fact that a potential change persists indefinitely if a static displacement of tectorial membrane relative to the reticular lamina is maintained mechanically, leads to the conclusion already stated that *the energy of the electrical re-*

and to the relations between movement and potential, and between potential and nerve impulses

We conceive that, as the basilar membrane, and the organ of Corti with it, bulge one way or the other, there is a shearing action between the stiff reticular lamina of the organ of Corti and the stiff but viscous tectorial membrane that lies in contact with it, because the tectorial membrane pivots around a different axis, as illustrated in Fig 7 The shearing action bends the hairs of the hair cells, which are attached both to the organ of Corti and to the tectorial membrane This bending is the mechanical movement that is critical for stimulation Protection against too great bending is probably provided by the attachment of the tectorial membrane directly to the outer and inner borders of the organ of Corti

The longitudinal bending causes longitudinal vibratory movements among the cells of the organ of Corti, and presumably bends the hairs lengthwise of the cochlear partition The longitudinal bending is sharpest in the "cut-off" region on the apical side of the maximum and is probably negligible on the basal side It is uncertain as yet whether the external and the internal hair cells are equally sensitive to radial and to longitudinal bending of their hairs Probably they differ, and the differential stimulation of the two sets by the different directions of bending allows possibilities, through inhibitory neural interactions within the central nervous system, of sharpening the "place" aspect of frequency discrimination

The traveling waves are known to produce eddies in the cochlear fluids on the apical side of the position of maximal amplitude The forces that produce eddies, we believe, also tend to cause an unsymmetrical longitudinal shift or "creep" to the tectorial membrane relative to the organ of Corti Such a shift would cause a one-way longitudinal bending of the hairs This would be a mechanical rectifying action It allows the cochlea to "detect" efficiently and respond with nerve impulses to high-frequency acoustic signals above 2000 per second Just as the cochlear microphonic is the electrical sign of a symmetrical vibratory bending of the hairs, we believe the negative summating potential is the electrical sign of an unsymmetrical, rectified longitudinal shift This shift medullated dendritic branches of the primary neurons in the organ of Corti

At frequencies below about 300 c p s each sound wave acts like an individual stimulus to the nerve fibers Excitation apparently occurs during the "falling phase" of the cochlear microphonic, *i e* while scala media (and vestibuli) is becoming more negative relative to scala tympani This corresponds to the phase of *outward* movement of the stapes The phase relation of neural excitation to the cochlear microphonic is correct for the electrical theory, although this may not be immediately obvious The current flows from hair cell into nerve fiber and outward across the nerve membrane, and thus can excite the non-medullated dendritic terminals like one tremendous node of Ranvier, or like non-medullated fibers elsewhere Spatial summation between the several hair cells attached to a given nerve fiber is clearly positive, and also a facilitating action between summating potential and cochlear microphonic

This is at least a reasonable working hypothesis or "model" of the action of the cochlea as a sense organ

ACKNOWLEDGEMENTS

A more complete discussion of much of the material in this article, and a full list of references will be found in DAVIS, H "Biophysics and Physiology of the Inner Ear" *Physiol Rev*, 37 1-49, 1957

Some pertinent additional material appears in another paper entitled "Modification of Cochlear Potentials Produced by Streptomycin Poisoning and by Extensive Venous Obstruction," by the present author and his associates, in this volume

Several sections of this paper are taken almost verbatim from the chapter prepared by the present author for the forthcoming "Handbook of Physiology" of the American Physiological Society

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sponses is derived from the metabolism of the tissues, not from the acoustic stimulus The latter serves merely to "valve" the flow of energy from the biological source The result is an amplifier action in the sense organ prior to stimulation of the nerve fibers

The cochlear microphonic and the negative summating potential are believed to excite directly the nerve fibers in contact with the hair cells Only a passive role as electrical conductors is ascribed to the nerve endings No latency can be seen between mechanical displacement of the cochlear partition and the cochlear microphonic It is not yet clear whether there is synapse-like delay in excitation or whether the observed latency of action potentials (in the modiolus) should be attributed chiefly to conduction time in the non-

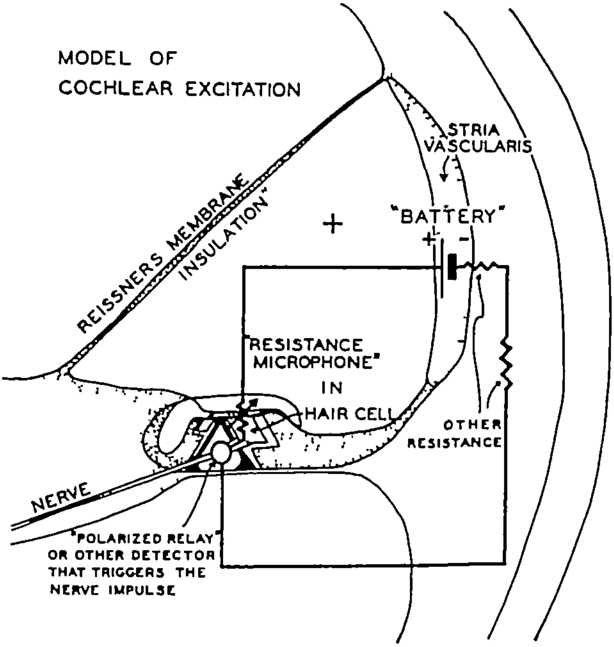

Fig 17 An electrical model of excitation of nerve impulses in the cochlea Additional batteries not shown in the diagram are located at the cell membranes of the hair cells and of the nerve endings The return circuit from nerve ending to the stria vascularis is not restricted to the narrow anatomical path indicated in the diagram but is diffuse through all intervening tissues except the scala media

greedy, he would ask for more direct observational data on the phase response of the cochlear partition, particularly at frequencies above 500 c.p.s., but to have the picture we have of the mechanical analysis is so good that we should not be very greedy. Taking advantage of the established reasonableness of the assumption of linear superposition, one can, at least in principle, determine rather approximately, as a function of time, the pattern of displacement of the cochlear partition in response to any specified acoustic stimulus, sinusoidal or complex, periodic or aperiodic.

My second comment has to do with two different theoretical points of view from which we can examine the next stage of the auditory process. By the next stage, I mean the transduction from mechanical displacement of the cochlear partition to excitation of the neurons of the auditory nerve. The first point of view is that of the audiologist, or the experimental psychologist, who wants to understand the overall behavior of the individual. The other point of view is that of the physiologist who wants to know exactly what does what.

A few years ago, we had only a very tentative picture of this second stage of the auditory process. The displacement of the cochlear partition squeezed the hair cells, the hair cells shocked the nerve fibers, and impulses went up the VIIIth nerve. Today, however, the mechano-neural transformation is the focus of research attention. Does it play a role in the sharpening of the mechanical frequency analysis? To what extent are its parameters under the control of higher centers? Does the band width of the "cochlear filter" vary with the alertness of the organism, with the listeners' set, with the task assigned?

It is evident from Dr. Davis' summary that those questions do not yet have positive answers, but equally evident that answers are at least on the way.

The primary concern of many of the researchers who are hard at work on the mechano-neural transformation is an understanding of the physiology of the process. What structures respond in what manner under what conditions? The main interest of many audiologists and psychologists, on the

Fig 1 STUHLMAN, O, JR "An Introduction to Biophysics" John Wiley & Sons, 1943

Fig 2, 4, 5 VON BÉKÉSY, G "Handbook of Experimental Psychology" John Wiley & Sons, 1951

Fig 3 WEVER, E G, LAWRENCE, M, and VON BÉKÉSY, G *Proc Natl Acad Sci U S*, 40 508, 1954

Fig 6 DAVIS, H *Jour Acoust Soc Amer*, 25 1180 1953

Fig 7, 8, 17 DAVIS, H "Physiological Triggers" American Physiological Society, 1956

Fig 9 VON BÉKÉSY, G *Jour Acoust Soc Amer*, 25 786, 1953

Fig 10 Data from SMITH, C A, LOWRY, O H, and WU, M L THE LARYNGOSCOPE, 64 141, 1954

Fig 11 TASAKI, I, DAVIS, H, and ELDREDGE, D H *Jour Acoust Soc Amer*, 26 765 1954

Fig 14 PESTALOZZA, G and DAVIS, H *Amer Jour Physiol*, 185 595 1956

TRANSMISSION AND TRANSDUCTION IN THE COCHLEA

Theoretical Discussion of Hallowell Davis' Paper

J C R LICKLIDER,*

Bolt Beranek and Newman Inc

Cambridge, Mass

My first comment on Dr Davis' masterful job concerns the theoretical significance of Professor Békésy's experimental contributions on the one hand, they displaced the speculations, most of which had been pretty far afield, about cochlear mechanics, and they sent the speculators scurrying up the auditory system to happier hunting grounds, on the other hand, they set the stage for a series of mathematical theories, not theories so much as assimilations, that reduced to formulas the essential schema of the cochlear mechanical frequency analysis

It is probably impossible to overstate the importance, to the rest of auditory theory, of having this solid foundation on which to build If one could ask for more without being greedy, he would ask for more direct observational data on the phase response of the cochlear partition, particularly at frequencies above 500 c p s , but to have the picture we have of the mechanical analysis is so good that we should not be very greedy Taking advantage of the established reasonableness of the assumption of linear superposition, one can, at least in principle, determine rather approximately, as a function of time, the pattern of displacement of the cochlear partition in response to any specified acoustic stimulus, sinusoidal or complex, periodic or aperiodic

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*Formerly at Massachusettes Institute of Technology

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It is evident from Dr Davis' summary that those questions do not yet have positive answers, but equally evident that answers are at least on the way

The primary concern of many of the researchers who are hard at work on the mechano-neural transformation is an understanding of the physiology of the process What structures respond in what manner under what conditions? The main interest of many audiologists and psychologists, on the other hand, is an understanding of the form of the transformation They are less interested in knowing what structures mediate it than they are in knowing the shape of the "transfer characteristic" Their hope, of course, is to apply the mechano-neural transformation to the signal that results from the mechanical cochlear analysis of the acoustic stimulus That would carry the quantitative description of the process through another stage and give us a picture of the incoming signal as seen by the nervous system

It seems to me worthwhile to distinguish between the advances in the two areas that correspond to the interests of the physiologist, on the one hand, and the audiologist or psychologist, on the other Let us consider them in reverse order

Insofar as the form of the transduction is concerned, the major advance, in what Dr Davis has described, is the demonstration that the cochlear microphonic potential is supplemented by the summating potential The microphonic normally is dominant at low frequencies and low intensities, the summating potential at high frequencies and high intensities The summating potential appears as though it were derived through rectification and smoothing of the microphonic potential, and those two operations give us a rough picture of the form of the process *From the recent developments,* we begin to see how the auditory system gets its extreme dynamic range We see also that its behavior in response to strong signals is fundamentally different from its behavior in response to weak signals

On the physiological side, the fundamental advance was the understanding that the cochlear potentials are energy-release phenomena and not direct-energy-transduction phenomena Relating the physiology to the anatomy, there is the clear evidence that the focal point of the process is the hair cell

When it comes down to the details of the process, however, the picture is extremely complicated There are actually seven potentials to be considered, and there are at least seven structures that are regarded by one investigator or another as playing important roles The opportunities for theory construction, here, are, therefore, obviously quite as good as they ever were in the study of the mechanical action of the cochlea I think that Dr Davis has displayed both great courage and great skill in his discussion of "which structure mediates which functions" He has at every step, I think, picked the best and currently most plausible hypothesis I am sure that he does not expect to be 100 per cent correct I should not be surprised, however, if he touched 95 per cent, and to do that is a tremendous accomplishment

TRANSMISSION AND TRANSDUCTION IN THE COCHLEA

CLINICAL DISCUSSION

John R Lindsay,

University of Chicago,

Chicago, Illinois

It is gratifying to the otologist to hear of the extensive research being carried on concerning the problems of hearing Dr Davis' presentation of evidence pertaining to the physiology of the hearing mechanism within the cochlea is of direct interest in the case of end-organ lesions, but does not lend itself readily to discussion from the clinical viewpoint I believe it would be more appropriate for the otologist to call attention to a few of the clinical problems which are in urgent need of investigation

The most common cause of serious hearing impairment in early adult life is the condition known as otosclerosis The cause of otosclerosis is not known, nor is there any known means by which the progress of the disease can be inhibited Although tremendous progress has been made in recent years in improving the hearing through surgery in certain selected cases of otosclerosis, there are many cases for which surgical procedures offer little or no help There are many cases which, because of progressive nerve loss, cannot be helped either by medical or surgical means, and a few for whom the modern hearing aids are inadequate other hand, is an understanding of the form of the transformation. They are less interested in knowing what structures mediate it than they are in knowing the shape of the "transfer characteristic." Their hope, of course, is to apply the mechano-neural transformation to the signal that results from the mechanical cochlear analysis of the acoustic stimulus. That would carry the quantitative description of the process through another stage and give us a picture of the incoming signal as seen by the nervous system.

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When it comes down to the details of the process, however, the picture is extremely complicated. There are actually seven potentials to be considered, and there are at least seven structures that are regarded by one investigator or another as playing important roles. The opportunities for theory case showing inner ear invasion by the measles virus In this case the finding could be described as an endolymphatic labyrinthitis resulting from direct invasion of the endolymphatic system by the virus by way of the stria vascularis

In a case reported some years ago by Professor Nager, the evidence indicated that a meningoencephalitis had been present with direct extension from the subarachnoid space to the perilymphatic compartment of the labyrinth There are also other types of cases in which clinical circumstances suggest that there may have been a direct extension of a virus infection or its toxic effects through the labyrinth windows from the middle ear The factual information regarding this type of injury to the inner ear is scanty In this, as in many other diseases of the ear, there is still a paramount need for histopathologic evidence as to what takes place in the inner ear and in the neural apparatus

One of the diseases which has been most intriguing to the otologist, and also to those of you carrying on research on the function of the cochlea, is that known as Ménière's disease The characteristics of the auditory disturbances in this condition have been unique With the accumulation of histopathologic evidence and the development of hearing tests much has been learned about this condition, however, certain features still remain inadequately explained The basic reason for the hydrops is not settled, and probably will not be finally determined until chemical analysis of the fluids have been further developed Information pertaining to certain features, such as the recruitment phenomenon, has been obtained through experimental procedures, however, the fluctuating low tone deafness seems to have so far eluded an adequate explanation Clinical observation has indicated that a Ménière's disease may exist without vertigo and without producing the distortions of the vestibular portion of the labyrinth characteristically found in those ears which have come from patients who had Ménière's disease with attacks of vertigo Histologic confirmation of this opinion that Ménière's disease may occur without vertigo has been afforded by a case which has recently come through our laboratory In this particular case there was no history of attacks of vertigo The character-

The cause of nerve degeneration associated with otosclerosis is not yet definitely known Dr Cawthorne has presented his view to you on this problem, yet on the basis of the histopathology in some advanced cases of otosclerosis there has been evidence of irritation of the inner ear and both degeneration of the sensory structures and a labyrinthitis ossificans

Factual information is also needed to explain the severe deafness which sometimes follows relatively mild trauma to the head Experimental work has furnished much information relative to acoustic trauma and the effect of high intensity noise on the inner ear, however, none of these experiments has adequately explained the profound deafness, sometimes unilateral and sometimes bilateral, which may result from striking the head on the pavement, for example, without causing unconsciousness and sometimes without evidence of fracture

It appears from the clinical course that in this type of case the pathology differs from that produced experimentally by severe blows to the head It is not explained on the basis of a transverse fracture of the pyramid, since there is no X-ray evidence, and there is sometimes some recovery of function

Another group of inner ear disturbances about which we have had very little information regarding the underlying pathology is due to virus diseases Deafness has been a frequent complication of some contagious diseases, particularly mumps, measles and typhus Sudden severe inner ear deafness has occurred sometimes in relation to a simple upper respiratory infection with or without a non-suppurative otitis media, or as a part of certain less common syndromes affecting also the ocular apparatus, the salivary glands or the central nervous system and meninges There has been an almost complete lack of information as to pathogenesis and pathology The only virus disease in which the histopathology of an inner ear complication has been demonstrated has been measles We have been able to find only two definitive reports on the pathologic picture produced by the measles virus in the inner ear, and we have recently added one bilateral case showing inner ear invasion by the measles virus In this case the finding could be described as an endolymphatic labyrinthitis resulting from direct invasion of the endolymphatic system by the virus by way of the stria vascularis

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There are many other problems pertaining to hearing impairment which are far from being adequately explained One of the greatest problems which has faced the research worker in the field of hearing has been the difficulty in obtaining factual information regarding the pathologic process which has produced the disturbance

It is obvious that a primary requirement for the understanding of disturbances of function is a complete knowledge of the physiological processes involved in hearing and maintenance of equilibrium It is, however, evident to the otologist that there are great gaps in information regarding the pathologic states which cause the functional disturbances, and that increased efforts to obtain such inforamtion is an urgent need

* * *

WEDNESDAY AFTERNOON SESSION

The International Conference on Audiology convened at 2 o'clock P M , in the Auditorium of the Washington University School of Medicine, St Louis, Missouri, Dr Joseph Erlanger, Washington University School of Medicine, presiding

NEURAL MECHANISMS IN AUDITION

Robert Galambos,

Walter Reed Army Institute of Research,

Washington, D C

My discussion of Listening and Pitch Perception will of necessity be brief, for in the 30 minutes at my disposal I shall be obliged to paint the picture with a very wide brush Recently published accounts of these matters are, however, available for those of you who wish more details [1,3,17-18]

LISTENING

I am sure all of us here recognize the distinction between "listening" and "not-listening" During this Congress we have heard the phenomenon referred to repeatedly, with such terms as "central deafness," "central factors in deafness" and "hearing but not perceiving" being employed The main idea behind these concepts is that while the cochlear apparatus within the temporal bone may be entirely normal and fully capable of arousing impulses in the auditory nerve, a central auditory apparatus must also be acting in a special and particular way if sounds are to provoke responses from animals and men A moment's reflection tells us that the brain must indeed be organized in one way when we listen and in another way when we do not One of the tasks of the auditory neurophysiologist, it seems to me, is to define as best he can the difference between these two states

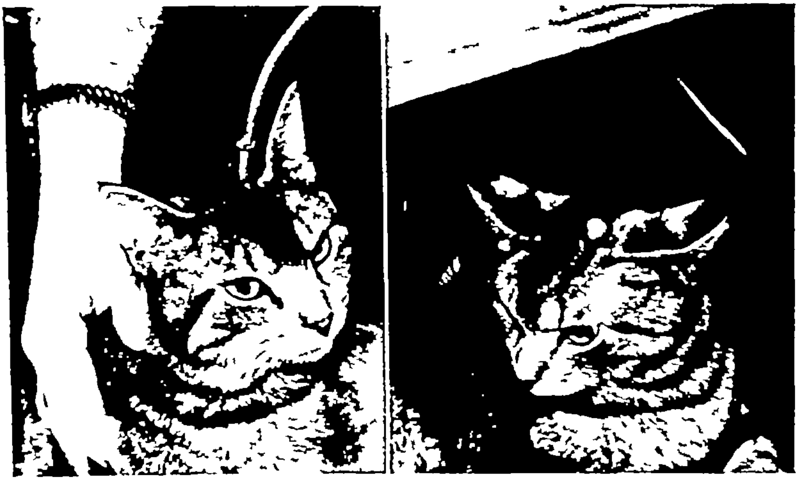

Fig 1 Cat with eight Implanted Electrodes for E E G Studies

Various attempts to do this have employed cats like that shown in Fig 1[7,9,10] Wire electrodes were implanted in the brain many weeks earlier, and these were led to the outside through the connector seen attached to the skull In this way the E E G was made available for study whenever desired, and the animal could be examined at any time in the unanesthetized state

Fig 2 shows some records from such an animal The upper line in each section shows the time at which an auditory stimulus—in this instance a click of moderate intensity—was presented through a loudspeaker Notice that the E E G response to this sound is not uniform in size in the cochlear nucleus or the auditory cortex, and that on occasion the stimulus evokes responses from parts of the brain (caudate nucleus) not considered in text books to be part of the auditory system of neurons The study of many records such as this suggests the conclusion that auditory stimuli of constant strength do

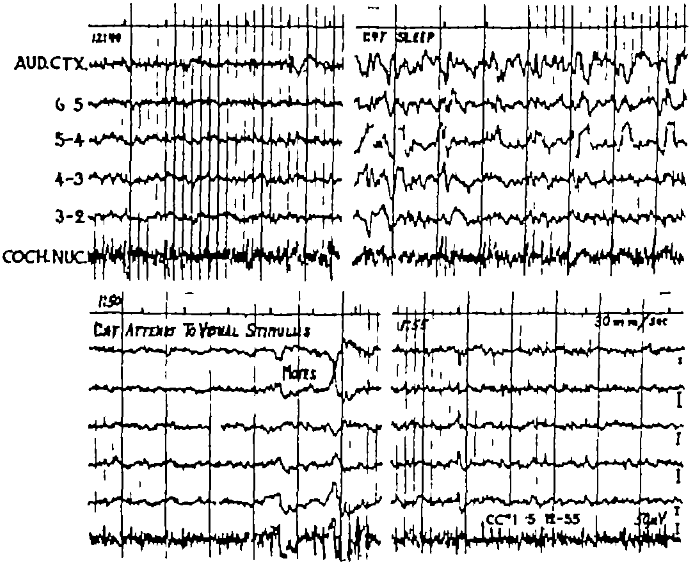

Fig 2 Brain responses to click stimuli from a cat like that shown in Fig 1 Electrodes 2 through 6 are located 2 mm apart in the Horsley-Clarke A-18 plane 6 and 5 are in subcortical white matter and 4 3 and 2 are in the caudate nucleus The size of the brain response obtained to a constant click stimulus seems to depend upon such variables as sleep and attentiveness

not invariably produce the same effects upon the brain, nor are their effects limited to those brain areas conventionally considered to be auditory in function

The demonstration that a fixed stimulus may yield a fluctuating brain response leads naturally to the question of whether the response is large when the animal "listens" and less so when it does not This idea is clearly suggested in Fig 2, where the cat attends to a visual stimulus, the animal is probably not attending to the click at that time, and the diminished size of the response to clicks may be taken to correspond with this fact

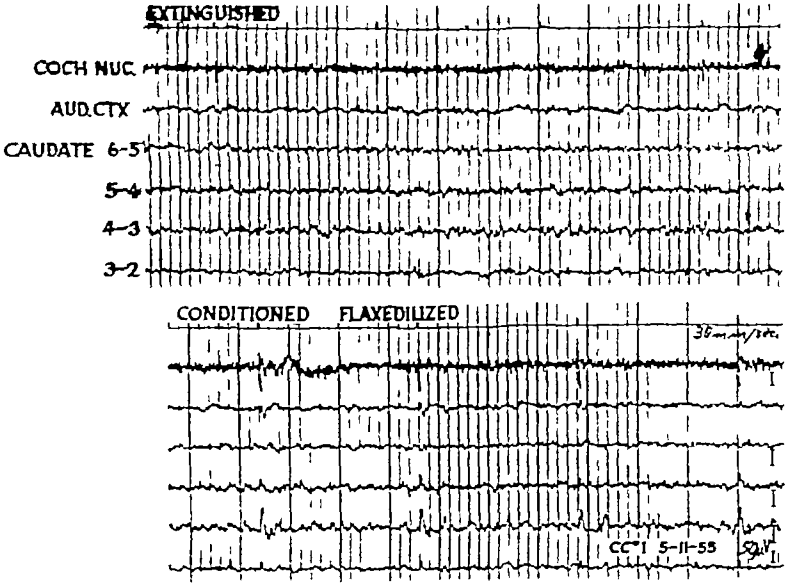

Fig 3 Effect of a simple conditioning procedure upon the amplitude of response evoked by click. Upper record small amplitude responses from animal exposed to click day and night for many days lower record larger amplitude to same click after it had been paired with shock To prevent muscle artifacts the animal was treated with a curare-like substance prior to the lower recordings

In the attempt to explore this possibility systematically the recordings of Fig 3 were made The records in the lower part of that figure were made after the clicks had been paired with shocks to the skin Responses to the clicks are uniformly large in size It was our intention to condition the cat to expect a shock in the presence of the click, and apparently the clicks did ultimately become a signal for the cat that an unpleasant event was about to occur The records in the upper part of the figure, on the other hand, had been made at an earlier time when the cat had been in the presence of the same click for many hours, and seemed to be paying no attention whatever to them, the E E G responses to clicks turn out, as expected, to be relatively smaller and considerably less widespread throughout the brain in the habituated as compared to the conditioned state[7]

The variation in amplitude of the auditory cortical responses in Fig 3 will come as no surprise, since it is generally thought that the cortex participates in some important way in the attentive function under exploration The demonstration that much the same phenomenon takes place in the cochlear nucleus, however, demands that the auditory nervous system throughout its entire length be under the control of neural mechanisms that modulate incoming messages, allowing impulses to pass at one time and preventing their passing at others Unfortunately, we do not completely understand what these controlling mechanisms actually are, but an examination of the known anatomy of the auditory system provides some speculative possibilities

Fig 4 shows, on the left, the classical ascending fiber pathways shown in most text books, as well as the newer routes by way of the reticular formation and to the cerebellum that have come to be known over the past 15 years (see[3]) On the right, by contrast, are shown the fiber tracts that descend from the cortex to end up finally in the cochlea itself This descending system was known in part to Cajal, to Lorente de No and to others of the classical schools of neuroanatomy, but the modern concept of its course and distribution is due largely to the efforts of Dr Grant Rasmussen His most notable contributions[12, 13] have shown that a bundle of fibers originating in the region of the superior olivary nuclei terminates on or near the internal hair cells This olivocochlear bundle represents the terminal line in the neural path that originates at the cortex, descends in close approximation with the classical ascending auditory fibers, and makes synaptic connections in many, if not all of the auditory nuclei One may speculate that it is through the action of this descending collection of fibers that modulation of the incoming messages occurs, something being "fed" or even "fed back" into the system to provide the control Such speculations at the present time also involve to varying degrees the limbic system in the forebrain and the reticular formation in the mesencephalon, but these details need not be stressed further Instead, let us consider some evidence that the olivocochlear bundle of Rasmussen has a definable physiological function in the cat, and by inference in any other animal (including man), with a bundle of Oort in its VIIIth nerve complex

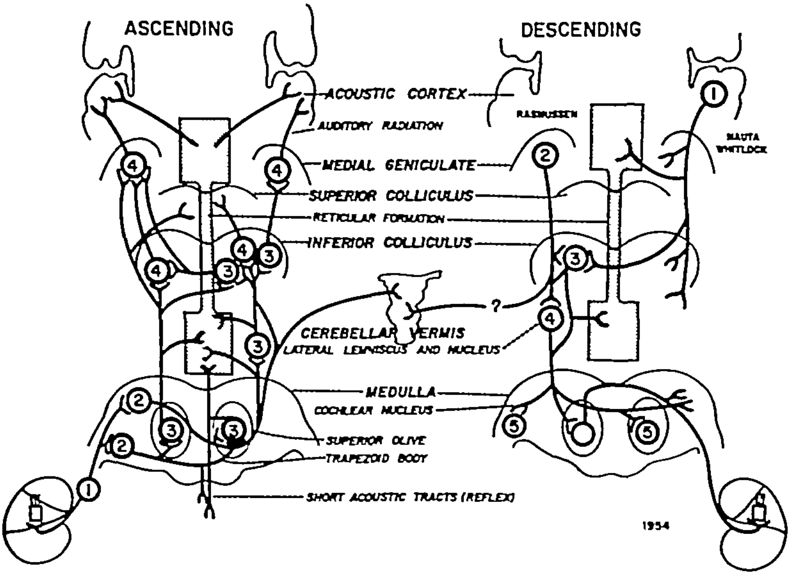

Fig 4 Diagram of the auditory pathways showing ascending and descending connections

Fig 4 summarizes the essential feature of this study,[4] showing that the amplitude of the auditory nerve response to a click stimulus is significantly reduced if a barrage of impulses is simultaneously arriving at the cochlea via the olivocochlear bundle This final link in the descending chain of neurons thus has an inhibitory effect upon the auditory system, preventing the arousal of the expected amount of nerve activity to a standard click stimulus It should be noted that this inhibition was demonstrated by delivering electrical shocks to the medulla of anesthetized cats, and that it has not as yet been shown to occur naturally in normal animals, so we cannot be certain in extrapolating these data to the normal case, nevertheless, the final link in the descending system acts as an inhibiting mechanism in these physiological preparations, and from this fact we may, perhaps, be

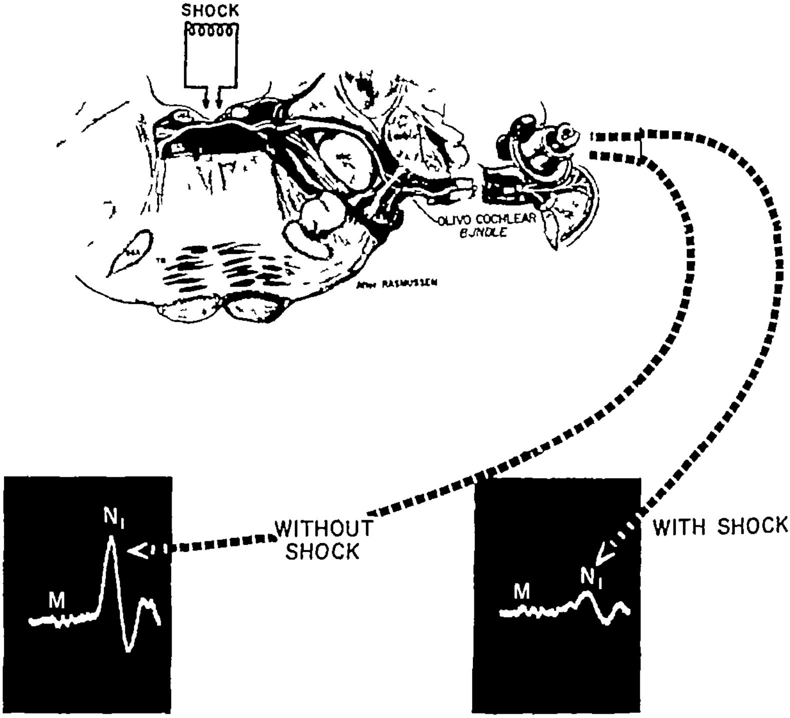

Fig 5 Anatomical plan of the olivocochlear pathway and illustration of its function The cross section shows cells of origin (OSA) and anatomical course of fibers to the cochlear spiral Shocks applied where the fibers decussate markedly reduce the amplitude of the auditory nerve discharge (N_1) evoked by a click without influencing the hair cell response (M)

permitted to infer that the probable role of the entire system in the normal animal is at least in part an inhibitory one

These first efforts to study the problem of "listening" can be summarized as follows The attentive animal is characterized by large E E G responses spread throughout its brain, areas being included that ordinarily are not considered to be part of the auditory system The inattentive animal shows responses in fewer brain locations, and these are small in size The variation in size occurs throughout the auditory system, being apparent even at the cochlear nucleus, the first synapse in the auditory system The descending pathway represents a possible neural mechanism for causing the amplitude variations, and its final link, the olivocochlear pathway, is known to function as an inhibitor Much obviously remains to be done, however, before the problem is finally solved

PITCH PERCEPTION

Of all the problems of hearing, that of how we perceive pitch has undoubtedly received the lion's share of attention by experimentalists Many recent reviews of this topic are available,[1 3 1- 18] and so my efforts today need not attempt comprehensiveness Instead let us consider some old and new studies with microelectrodes that seem to illustrate the major principles thus far elucidated These microelectrodes, you will recall, allow the action potentials of a single brain cell to be isolated for study The way the cell responds to the variety of sounds to which the ear is subjected, constitutes the raw data out of which an understanding of the brain is to be fashioned If we collect data from a sufficiently large number of such cells we can hope to create a complete and satisfactory picture

Fig 6 presents some of the earliest records taken from the auditory system with this technique[5] When the words "VIIIth nerve" were spoken in the vicinity of the cat, a unit in the cochlear nucleus reacted briskly, as is shown there It has since been repeatedly demonstrated that auditory units in all the auditory nuclei are similarly sensitive to sounds, and when pure tones are employed they respond to a limited and restricted band of them This fact is demonstrated for

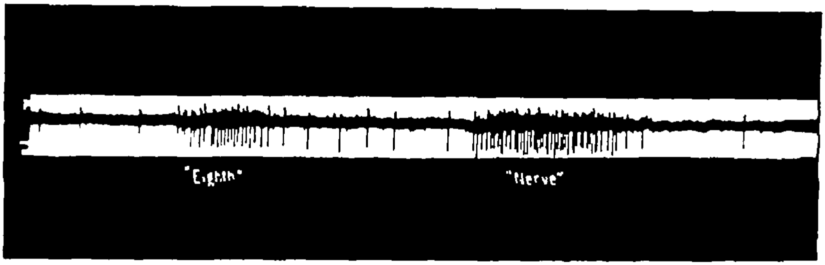

Fig 6 Response of a single cell in the cochlear nucleus to spoken words Microelectrode recording from anesthetized cat

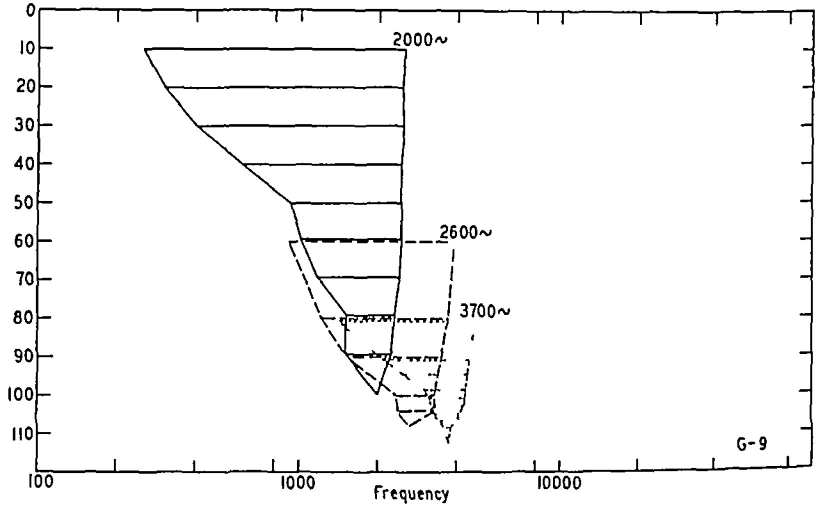

Fig 7 Response areas for three separate cells in the cochlear nucleus of the anesthetized cat Ordinate intensity in db below reference level for tones given on abscissa The 'best frequency of each cell is written next to the triangular response area that encloses all tones found adequate for its stimulation

three units in Fig 7, where the tones that excite any given unit are seen to fall in a limited part of the sound spectrum The triangular "response area" thus experimentally defined proves conclusively that auditory units function physiologically in the manner suggested by their anatomical connections, namely, by responding to limited bands of tones The basic idea of Helmholtz, which was that some unique spatial correlate exists in the brain for each perceived tone is, therefore, essentially confirmed, although the details of how this comes about is a somewhat more elaborate story than I can give you here (but see [1 3 15 16])

Fig 8 shows the experimental demonstration of the place principle in the case of the cochlear nucleus [14] The path of a microelectrode track is shown there in a saggital section of the nucleus The electrode entered the dorsal cochlear nucleus from behind and proceeded successively through the posterior and anterior ventral cochlear nuclei The numbers in Fig 8 represent the tone frequencies found by physiological methods to be best represented at the indicated position It is clear that an orderly arrangement exists in the various segments of this complex nuclear mass A similar tonotopic arrangement has been uncovered throughout the auditory system wherever it has been sought experimentally

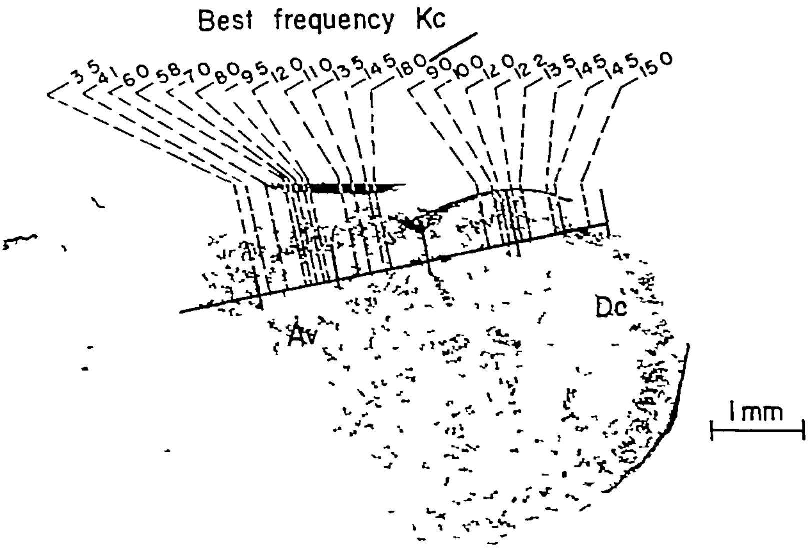

Fig 8 Plot, on a saggital section of the cochlear nuclei of the cat, of the best frequencies encountered during a particular microelectrode puncture Note orderly decline of frequency in both the dorsal (Dc.) and the anterior ventral (Av) segments indicating that projection of the basilar membrane to this nuclear mass is tonotopic

We can conclude, therefore, that the evidence is heavy in support of the idea that the place in the brain where a tone

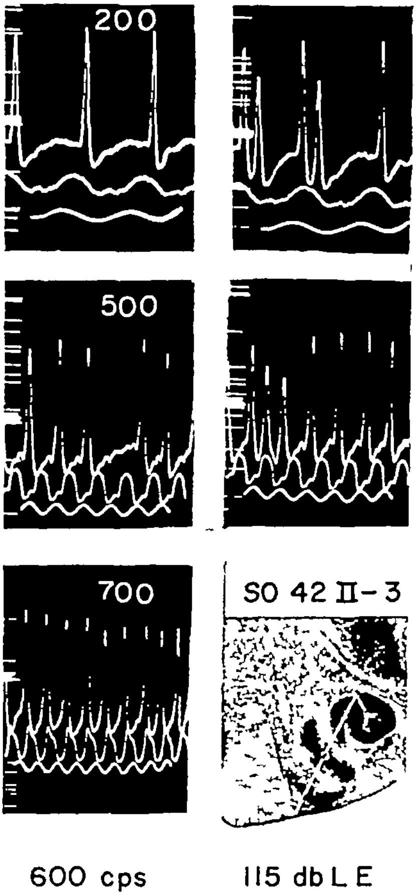

Fig 9 Responses of a single cell to tones Anesthetized cat Electrode location lower right accessory superior olivary nucleus Each segment of the figure shows at left the spontaneous activity of the unit and on the swept traces the unit response (top line) the cochlear round window response (middle) and the electrical signal delivered to the earphone (bottom The tone frequency employed is written on the left member of each pair of records to which it pertains The best frequency for this unit was 600 cps the stimuli were applied to left ear with recording on the right side

produces its effects is somehow important for our ability to perceive pitch, but what about that other persistent idea of how tone frequency is handled, namely, that each nerve fiber responds at the frequency of the tone? Fig 9 shows that, to a remarkable extent, this idea is correct also The unit pictured there was isolated in the superior olive[6] It responded to tones up to 1100 cps, and the pictures make it clear that it often did so by discharging once to each sound wave cycle The pictures also make it evident, however, that the unit sometimes skipped responding, and that it would on occasion respond twice to a single sound wave cycle The facts, nevertheless, unequivocally support the idea that tonal frequency can be centrally represented as nerve discharge frequency We do not as yet know precisely how to evaluate the relative importance of the two principles—place and frequency of nerve discharge—in the mechanism of brain action that results in pitch perception We can be certain only that the frequency principle must be of limited utility for tones above 1000 or 2000 cps

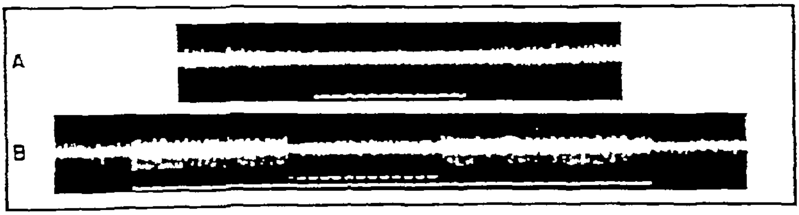

Fig 10 Suppression of cochlear nucleus cell responses by tones Anesthetized cat A.—The spontaneous activity of a unit disappears so long as a tone (white line below record) is on B—A unit excited by one tone (long white line) stops completely so long as a second tone (short line) is simultaneously sounding

Besides the place and frequency principles there are at least two other facts about the auditory brain that almost certainly are relevant to the pitch problem The first of these is that a low tone activates a larger amount of the auditory brain than does a tone of high frequency This is true, because the pattern of cochlear motion aroused by low tones spreads from base to apex along the basilar membrane, thus sweeping across the entire neural complement of the cochlea The pattern evoked by high frequency tones, by contrast, is restricted to the base The consequences of this fact are not entirely understood, but it is already clear that any partial damage to the VIIIth nerve that involves fibers from the various parts of the basilar membrane in equal proportions yields a selective loss of hearing for high frequencies [8, 11]

The second ancillary fact is illustrated in Fig 10 We ordinarily think of the auditory stimulus as creating excitation, or increased nerve activity, when it is presented to the ear This is certainly the case for many single units in the brain, as can be seen in Figs 6 and 9 In Fig 10, on the other hand, what the stimuli do is to suppress the ongoing activity rather than to create more of it (see[2]) This inhibitory effect of tones is a general phenomenon observable at all levels in the auditory system including the cortex

This demonstration that a particular tone causes certain units to stop firing and others to fire more briskly, probably means that the overall effect of the tone is to create areas of activity interspersed among cellular areas in which activity has been suppressed Presumably the exact locations and extents of such excited and inhibited areas are of significance as central correlates of the tonal frequency (see[3]), but no clear picture of how this exactly occurs can yet be given

There are, then, the four factors known to play some role in the central mediation of the experience of pitch The well-known place and frequency principles clearly are in operation The "place" involved by a given tone must, however, be conceived as collections of neural loci, in some of which increased activity occurs, whereas decreased activity occurs in others The configuration of excited and inhibited "places" varies as the tone frequency changes, and this geographical (tonotopic) correlate for pitch is the one most securely established by experimental data The "places" involved, finally, are more extensive and widespread through the auditory nuclei when the tone is low as opposed to high in frequency How the central nervous system produces the sensation of a tone out of these bits and scraps of information remains a complete mystery

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PHYSIOLOGICAL DISCUSSION

ICHIJI TASAKI,

National Institute of Neurological Diseases and Blindness,

Bethesda, Md

DR. I TASAKI Dr Galambos has just given us a very interesting survey of the problem of how the nerve fibers and cells in the auditory pathway transmit nerve impulses to the central nervous system He has shown us clearly that the function of the auditory pathway is not only to transmit messages to the central nervous system but also to assort and classify the messages before they reach the brain, or sometimes, to eliminate some of the messages before they reach the cerebral cortex Now I should like to discuss the problem before us very briefly from a slightly different angle, namely, in relation to our present day knowledge of more general mechanisms found in the nervous system

Sometime ago, Dr Davis and I demonstrated the fact that the auditory nerve fibers arising in the basal turn of the guinea pig cochlea respond to tones of any frequency, high and low, while the fibers originating in the apical turn respond only to low frequency tones (slide) These nerve impulses in the individual auditory nerve fiber obey the all-or-none law They will not stop until they arrive at (or near) the synapses in their pathway The behavior of these synapses in the auditory system is probably very similar to that of other excitatory or inhibitory synapses in the nervous system, therefore, physiological studies on the auditory pathway are , in a sense, a sort of experimental study on synaptic transmission in the nervous system If the pattern of the nerve impulses arising in the cochlea is accurately given, the fate of these impulses will be determined simply by the structure of the nervous system This part of the problem is not specific to the auditory system

The problem dealing with initiation of nerve impulses in the cochlea is, on the contrary, very specific to the auditory system, because the structure of the inner ear is very different from that of other mechanoreceptors Let us take a look at a picture illustrating the familiar structure of the cochlea (slide) When we introduce a glass pipette electrode into various parts in the cochlea, it is found that the electric potential in the space occupied by endolymph is 80-90 mv positive to that of the perilymph (Békesy) It appears to us that the fluid in the space between the basilar membrane and the reticular lamina is 70-80 mv negative to the perilymph

These dc potentials can be interpreted as devices for increasing the sensitivity of the nerve fibers to electrical stimuli Microphonics and other slowly changing potentials are undoubtedly signs of intermediate processes which link the mechanical events with the process of initiation of nerve impulses

A few days ago Dr Rasmussen gave us a special strain of guinea pigs, waltzing guinea pigs He gave us three of them, and we used four, that means we took one more after he left to attend this meeting These guinea pigs show no sign of microphonic responses They have no hair cells in the cochlea The story that the hair cells are responsible for generation of microphonic responses is safe, but, we found a dc potential of about 80 mv in the endolymphatic space and also a strong negativity in the space between the reticular lamina and the basilar membrane A few years ago somebody around here made an attempt to attribute the endolymphatic dc potential in the cochlea to the function of the hair-cells That was a mistake, my mistake At present there is no doubt that the positive potential is generated by some oxidative metabolism in the stria vascularis

In conclusion there is a very intriguing problem in Dr Galambos' presentation. That is the problem of how the electric responses in the auditory nerve fiber are suppressed by stimulation of the olivocochlear nerve bundle In general, it is extremely difficult to suppress an all-or-none response in the nerve fiber All the inhibitory processes that have been demonstrated in other parts of the nerve system take place at the site of initiation of nerve impulses, namely, at the pace-makers

I am assuming that Dr Galambos' electrical stimuli were limited to the fibers in the olivocochlear bundle Under this assumption, the most probable explanation of the phenomenon is to attribute it to secretion of some inhibitory substance which raises the threshold of the nerve endings to mechanical stimuli A somewhat similar phenomenon has been reported recently by Dr Leowenstein in the mechanoreceptor in the skin (*Nature*, 178 1292, 1956)

ANATOMICAL DISCUSSION OF THE PAPER GIVEN BY DR GALAMBOS

GRANT L RASMUSSEN,

National Institute of Neurological Diseases and Blindness,

Bethesda, Md

I have closely followed the studies of Dr Galambos during the past several years, and have often wondered about the function significance of this strange system of auditory neurons which course backward in an unorthodox fashion

It is not necessary to review the general plan of the ascending and descending auditory pathways, since Dr Galambos has already done this with the aid of his Fig 4 To be sure his schema of the circuits was necessarily simplified for his presentation

Our main interest presently concerns the less well-known descending or recurrent conduction chain of auditory neurons which extends from the cerebral auditory cortex to the cochlea itself It has been possible to reveal this system of fibers by means of axonal and terminal degeneration methods[1 2 3 4] These fibers are for the most part intermixed with those of the ascending system, which constitutes by far the greater number of fibers The recurrent fibers hold constant positional relationship and, moreover, are interconnected in an orderly fashion, projecting from definite cell groups of higher levels to particular cells of any one of several auditory nuclei For example, certain neurons of the inferior colliculus and dorsal nucleus of the lateral lemniscus connect bilaterally with particular cell groups of the dorsal cochlear nucleus, and of the superior olivary complex, thus we see evidence of a certain specificity in the descending system, the meaning of which is not understandable to me at this time

Having described some of the general anatomical features, I will now present a more detailed description of the pattern of distribution of the descending system, as found at the level of the brain, which holds most interest at this time I show a figure of a transverse cut of a cat's medulla oblongata at the level of the olivary complex and olivo-cochlear bundle, which includes also the cochlea This is similar to Fig 5, shown by Dr Galambos, except that here the recurrent fibers coming from the inferior colliculus are displayed

Here within the confines of the circumscribed area indicated, are scattered fibers which degenerate following a lesion of inferior colliculus and/or dorsal nucleus of the lateral lemniscus Some of these fibers enter and terminate in that part of the olivary complex that has been previously determined as the site of origin of the olivo-cochlear bundle, the fibers of which terminate in the cochlea perhaps about hair cells, however, substantial anatomical proof is still lacking on this point

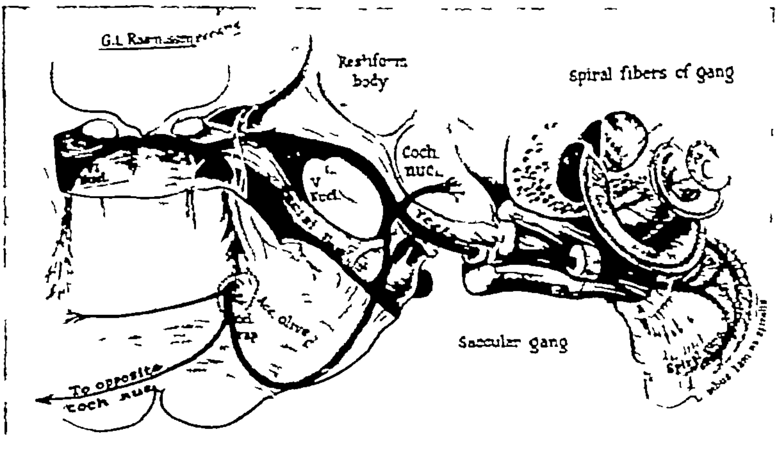

Fig 1.

While some fibers end in the medial two segments of the olivary complex, a very impressive number of fibers continue on through the trapezoid body to reach and disperse themselves within the dorsal cochlear nucleus of both sides

This may well be one of the important pathways concerned with suppression of neural activity of the cochlear nucleus from higher levels, as has been mentioned by Dr Galambos

This efferent packet of fibers that enters the cochlear nucleus would seem to be identical with that first described by Held,[5] and later by Lorente de Nó,[6] in Golgi preparations While both recognized its efferent nature, neither were able to determine whence it came

Finally, I would like to mention that in recent studies I have been able to demonstrate anatomically several other recurrent contributions to the cochlear nucleus that originate from brain regions not usually considered auditory in function

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CLINICAL DISCUSSION OF THE PAPER GIVEN BY DR GALAMBOS

J S RIESCO MAC-CLURE,

Neuro-Surgical Institute,

Santiago, Chile

I am afraid that what I have to say from the clinical point of view is not very satisfactory, because I have been more concerned with vestibular disturbances than with those of the cochlea, however, I will refer to the lesions in the brain stem, lesions due to tumors, encephalitis, hemorrhages and concussions Between 1950 and 1957 we have seen 76 cases of this kind at the Neurosurgical Institute in Santiago, Chile The contrast between the rich vestibular symptomatology and the poor cochlear symptomatology is surprising

Disorders of the equilibrium, spontaneous nystagmus and positional nystagmus, and marked alterations in the caloric responses were found in almost 100 per cent of the cases On the other hand, the audiometric examination was always normal, or almost normal, even in those cases in which a bilateral vestibular paralysis was found Precisely this cochlear and vestibular dissociation, in which the vestibular nerve is paralyzed and the cochlear is normal, is an important sign of a destructive lesion in the vestibular area of the floor of the fourth ventricle

We have been anxious to see what happens when only the cochlear nucleus at the medulla is involved We believe that the following case shows something A 20-year-old man was admitted at the Neurosurgical Institute with the suspicion of a brain tumor After an exhaustive neurological examination, and after a two-month follow-up, the diagnosis of encephalitis due to virus infection was made Before becoming ill this young man never complained of hearing loss nor loss of balance

The audiogram showed a normal left ear and a hearing loss of the ascending type in the right ear with no recruitment, but with diplacusis At the same time the calorigram showed a total paralysis of the right vestibular branch and paresis of the left vestibular branch Even more, with water at 18 degrees during a 60 second irrigation a perverted vertical nystagmus was seen

The patient also had spontaneous nystagmus to the left, a marked loss of balance and involvement of the VIth nerve on both sides In the absence of recruitment, bilateral cochleo-vestibular dissociation, perverted nystagmus, and neurological involvement of central nature of both VIth nerves, we diagnosed a partially destructive lesion of the floor of the fourth ventricle Not only a partially destructive lesion of the vestibular area, but also a partially destructive lesion of the right cochlear nucleus, was found

This efferent packet of fibers that enters the cochlear nucleus would seem to be identical with that first described by Held,[5] and later by Lorente de Nó,[6] in Golgi preparations While both recognized its efferent nature, neither were able to determine whence it came

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Neuro-Surgical Institute,

Santiago, Chile

I am afraid that what I have to say from the clinical point of view is not very satisfactory, because I have been more concerned with vestibular disturbances than with those of the cochlea, however, I will refer to the lesions in the brain stem, lesions due to tumors, encephalitis, hemorrhages and concussions Between 1950 and 1957 we have seen 76 cases of this kind at the Neurosurgical Institute in Santiago, Chile The contrast between the rich vestibular symptomatology and the poor cochlear symptomatology is surprising

Disorders of the equilibrium, spontaneous nystagmus and positional nystagmus, and marked alterations in the caloric responses were found in almost 100 per cent of the cases On the other hand, the audiometric examination was always normal, or almost normal, even in those cases in which a bilateral vestibular paralysis was found Precisely this cochlear and vestibular dissociation, in which the vestibular nerve is paralyzed and the cochlear is normal, is an important sign of a destructive lesion in the vestibular area of the floor of the fourth ventricle

We have been anxious to see what happens when only the cochlear nucleus at the medulla is involved We believe that the following case shows something A 20-year-old man was admitted at the Neurosurgical Institute with the suspicion of a brain tumor After an exhaustive neurological examination, and after a two-month follow-up, the diagnosis of encephalitis due to virus infection was made Before becoming ill this young man never complained of hearing loss nor loss of balance

The audiogram showed a normal left ear and a hearing loss of the ascending type in the right ear with no recruitment, but with diplacusis At the same time the calorigram showed a total paralysis of the right vestibular branch and paresis of the left vestibular branch Even more, with water at 18 degrees during a 60 second irrigation a perverted vertical nystagmus was seen

The patient also had spontaneous nystagmus to the left, a marked loss of balance and involvement of the VIth nerve on both sides In the absence of recruitment, bilateral cochleo-vestibular dissociation, perverted nystagmus, and neurological involvement of central nature of both VIth nerves, we diagnosed a partially destructive lesion of the floor of the fourth ventricle Not only a partially destructive lesion of the vestibular area, but also a partially destructive lesion of the right cochlear nucleus, was found

Apparently these lesions were irreversible, because after six months, although the patient was much better from the neurological point of view, the functional examination of the VIIIth nerve gave exactly the same results

We believe, then, that the deafness due to a lesion of the cochlear nucleus is very similar to the deafness due to an acoustic tumor Unfortunately, we have not done the speech tests in our patients because, as I have already pointed out, we have been more concerned with the vestibular system

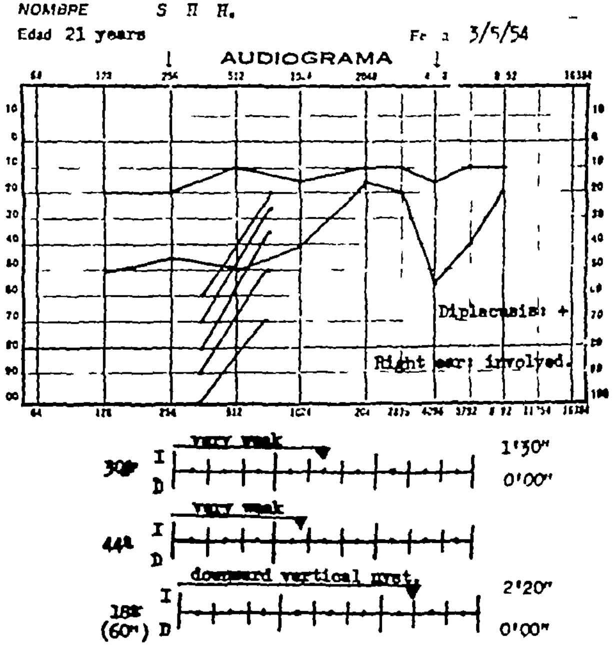

Fig 1

Dr Lindsay has described what he calls "deafness of sudden origin and indefinite etiology" It is possible that some of these cases are due to lesions in the cochlear nuclei

A 19-year-old woman awakened one morning with strong tinnitus and total deafness in the right ear She also had some dizziness and loss of balance, but she could continue her school duties We saw her four months after this had happened The otoscopic examination and the vestibular tests were normal

The audiogram showed a nerve type of hearing loss at right, with absence of recruitment and with a normal differential limen, which does not correspond to a lesion in the end-organ

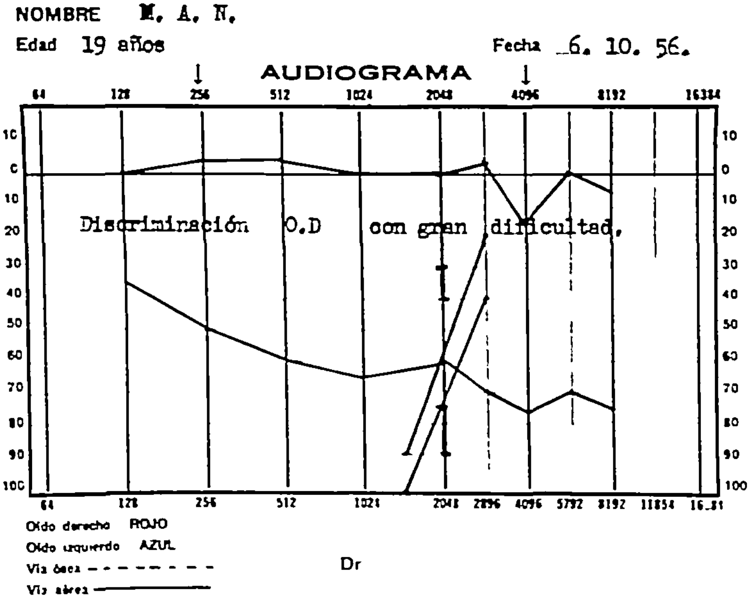

Fig 2

The fact that this deafness of sudden origin and indefinite etiology is possible of a complete or partial recovery, as we have seen in a few instances, suggests that the lesion is in the cochlear nucleus and not in the end-organ Obviously we are not talking about endolymphatic hydrops When recovery takes place, this happens in the first three weeks, not after We have seen patients who had a complete unilateral deafness, and within nine to 15 days were totally recovered We may assume that if the organ of Corti had been damaged no recovery would have been possible

Patients with stem brain lesions are not numerous, and when one is found, usually its general condition is bad As we are asked for a localization diagnosis, we go through all the functional examination of the VIIIth nerve, with particular emphasis on the equilibrium tests, cerebellar and vestibular tests (central and peripheral), which are most important for our purpose, however, we feel now that if the neurosurgeon is not in a hurry, and if the patient is not too bad, we can go through a more complete audiologic examination in order to correlate the clinical findings with the histopathological ones, as we have been doing with the vestibular disorders

For example, here is a case in which the cochlear study was very poor as compared with the vestibular interpretation A 47-year-old man had an adenocarcinoma of the thyroid gland with multiple metastasis in the lungs and in the central nervous system He died before any surgery was performed The VIIIth nerve examination showed, as usual, a very rich vestibular symptomatology, which led us to the diagnosis of a partially destructive lesion of the right vestibular area on the floor of the fourth ventricle According to the pathological findings, the diagnosis was correct, and an 8 mm diameter metastasis had partially destroyed the right vestibular nuclei, but we verified a peculiar hearing loss which we could not interpret

The audiogram showed that this patient had a slight hearing loss on left ear and moderate deafness on the right, with a Weber lateralized to the right The middle ears were normal The report of the pathologist showed that a small metastasis involved the right olive in the medulla

Another case, a 42-year-old man, had a clear symptomatology of a brain tumor headaches, vomiting and very marked papillo-edema, but the neurologists were doubtful whether the lesion, the tumor, was in the anterior or posterior cerebral fossae

If the neurological symptomatology was puzzling, the results of the VIIIth nerve examination were even more difficult to understand

He had no hearing at left, but the vestibular branch, ac-

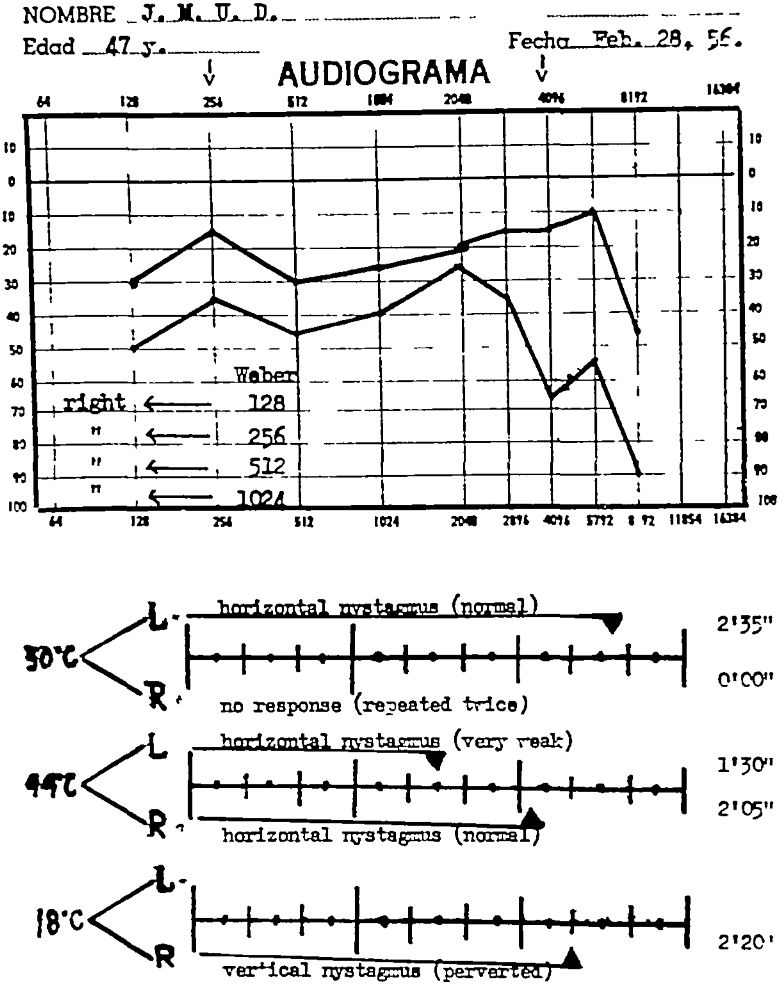

Fig 3

cording to the caloric response was normal On the right ear he had a moderate hearing loss, but no vestibular response Besides this inverted dissociation, he also had *a*, spontaneous nystagmus to the left, *b* positional nystagmus, *c* complete loss of balance—could not stand upon his feet, *d* bilateral hypotony, and, *e* ataxia in the finger-nose tests and adiadokocinesia These cerebellar symptoms were bilateral

From time to time we get cases such as this, in which the otoneurological diagnosis is almost impossible, because there is a cochlear paralysis with normal vestibular in one ear, and a cochlear paresis with a vestibular paralysis in the opposite ear. As though this were not enough, the patient had a definite central vestibular symptomatology and bilateral cerebellar symptoms.

You may ask: what did the electroencephalogram show? It showed abnormal activity in the right cerebral hemisphere.

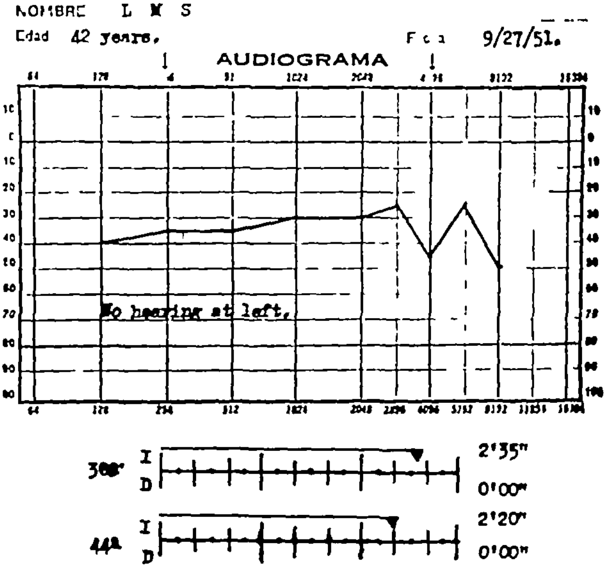

Fig 4

At the necropsy a large astrocytoma in the right cerebral hemisphere was found. It was a large, deeply located tumor which strongly compressed the brain stem at the incissura tentorii. This was undoubtedly the cause of the central vestibular symptomatology. The pathologist found that the tumor had invaded the right medial geniculate body and considered this lesion responsible for the left total deafness and right partial deafness.

The contrast between the rich vestibular symptomatology and the poor cochlear symptomatology in cases of brain stem lesions is surprising I should say rather that it is surprising the contrast between the attention we have given the vestibular disorders and the very reduced interest we have shown in the cochlear disorders

If any conclusion can be drawn out of these clinical observations, it is that, until the present moment, very few efforts have been made to learn what actually happens to the auditory function when there is a lesion of the brain stem

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FUNCTIONS OF THE AUDITORY CORTEX

WILLIAM D NEFF,

University of Chicago,[*]

Illinois

Because of the lack of appropriate clinical material, most of our knowledge of the functions of the auditory projection areas of the cerebral cortex must come from experiments done on animals other than man In the last fifteen years, considerable progress has been made in animal investigations Several factors have contributed to this progress

1 The use of electrophysiological recording and stimulating techniques to define more exactly the auditory pathways and centers in the central nervous system, *2* the use of new techniques of experimental surgery, *3* the development of improved methods of testing auditory discrimination, *4* the application of standard neuroanatomical procedures to discover new details of cortical and thalamo-cortical organization

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In the following paragraphs some of the results of recent studies which have investigated the role of the auditory cortex in sound discriminations, are briefly summarized Particular attention will be given to experiments done in our laboratory with only occasional reference to related studies done by other investigators Emphasis will be placed upon experiments, in which behavioral methods were used to test auditory discriminations before and after partial or total ablation of auditory cortex Since the auditory nervous system of the cat has been more thoroughly explored than that of any other animal, I shall confine most of my discussion to studies in which the cat was used as experimental subject Brief mention will be made of parallel studies which have been done on the monkey

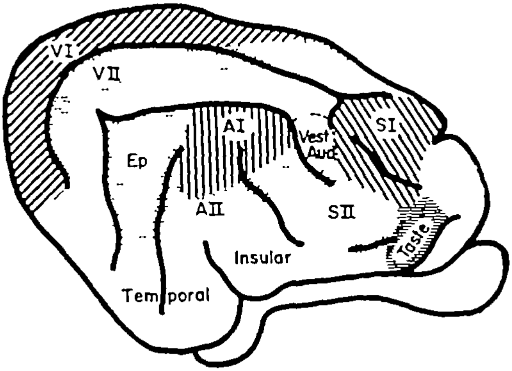

Fig 1 Cerebral cortex of the cat showing auditory areas I II, and Ep the insular-temporal region and projection areas of other sensory systems

The auditory cortex, as it has been defined for recent experiments, is shown in Fig 1 It consists of the areas labelled AI, AII, and Ep This map is based upon results from electrophysiological, cytoarchitectural, and retrograde degeneration studies[1 2 3 4]

In 1943, Kryter and Ades[5] reported that the absolute thresholds of the cat, as tested in a conditioned avoidance situation, were unchanged by bilateral ablation of a region which included all of AI, AII and Ep They made tests only in the frequency range from 125 c p s through 8000 c p s, but there is no later evidence to suggest that losses would have occurred for higher frequencies which the cat hears* A loss of the learned habit occurred as a rule after the bilateral cortical ablations, but relearning was at least as rapid as initial learning

In similar studies, Raab and Ades[7] and Rosenzweig[8] have shown that no loss in capacity to discriminate small changes in intensity occurs after bilateral ablation of AI, AII, and Ep Again the learned habit is affected, but post-operative relearning is rapid

Several studies have shown that the auditory cortex of mammals (at least of the cat, dog and monkey) has a tonotopic organization, *i e*, as measured by electrophysiological recording from gross electrodes a given point on the cortex has a lower response threshold for a particular frequency, or narrow band of frequencies, than for other frequencies in the audible range[9 4 10] Because of this tonotopic organization, it has often been suggested that the auditory cortex may be particularly important for discrimination of changes in frequency

Experiments done by Meyer and Woolsey,[12] and by Butler, Diamond, and Neff,[13] have shown that this is not true Fine discriminations of frequency can be made after complete bilateral removal of AI, AII, and Ep

For a number of reasons, a particularly important one being a consideration of experimental evidence on functions of visual cortex, it might be inferred that the auditory cortex plays an important part in pattern discrimination This inference is true, at least for discrimination of temporal patterns of tones Diamond and Neff[14] have shown that after complete bilateral ablation of AI, AII, and Ep, cats cannot discriminate two tonal patterns, one consisting of three tonal pulses arranged in the sequence, low-high-low, and the other of the same tones presented in the sequence, high-low-high If a region corresponding approximately to AI is ablated bilaterally, the animal can make this pattern discrimination and, in fact, shows no post-operative loss of the learned habit. If all but a small remnant of auditory cortex is ablated bilaterally, there is amnesia for the learned habit, but relearning occurs. Jerison and Neff[15] have reported similar results for the monkey.

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*It has been shown that cats can learn to respond to tones at least as high as 60 000 c p s[6]

Another kind of discrimination, in which a deficit has been shown to occur after ablation of auditory cortex, is localization of sound in space. Neff, Fisher, Diamond, and Yela,[16] and Neff, Arnott, and Fisher,[17] have shown that cats are deficient in ability to localize sound in space after bilateral ablation of all or even of part of the auditory areas I, II, and Ep. After complete ablation of these areas, an animal will localize accurately an angle of about 40 degrees, whereas the normal animal, in the same situation, will localize a sound (buzzer) when the angle between separate positions in which it is presented successively is as small as 5 degrees.

From the post-operative study of the brains of animals used in some of the studies described above, and from studies done by Rose and Woolsey,[2] a fairly clear picture of the gross thalamo-cortical relationships has been obtained. After ablation of AI there is complete, or nearly complete, degeneration of the anterior half (approximately) of the principal part of the medial geniculate body. After ablation of AI, AII, and Ep the degeneration extends posteriorly to include the anterior two-thirds of the geniculate. Degeneration in the posterior part of the geniculate is found only when the ablation is extended into the insular and temporal cortex ventral to AII and Ep. In an unpublished anatomical study, Diamond, Chow, and Neff have shown that some degeneration of the posterior third of the medial geniculate occurs after experimental ablations confined to the insular-temporal region. From a careful analysis of the retrograde degeneration found in the medial geniculate after cortical ablation, it becomes clear that there is more than one kind of projection from the medial geniculate to the cortex. AI receives what Rose and Woolsey have termed "essential" projection, while AII, part of Ep, and the insular-temporal region receive "sustaining" projection, however, this two-category division is not sufficient, since it appears that the kind of projection to AII, Ep, and to the insular-temporal region may not be the same

Attention having been called to the insular-temporal cortex because of its anatomical relationship to the medial geniculate body, experiments have been started to determine the role it may play in auditory discrimination Results, which are not yet complete, indicate that frequency discriminations can be made after complete bilateral ablation of AI, AII, Ep, and the insular-temporal region (in some cases the ablations were also extended anteriorly in the ectosylvian gyrus to include somatic area II) A very surprising finding has been that a severe, and perhaps complete, loss of pattern discrimination occurs after bilateral ablation of the insular-temporal cortex alone, areas AI, AII, and Ep being left intact[18] This finding suggests that the insular-temporal region serves a function considerably more important than that of a receiving area for afferent impulses Its integrity may be essential for the normal functioning of the other auditory cortical areas, or it may have to do with the transmission and utilization of auditory information which is received and elaborated in areas I, II, and Ep A region homologous in terms of its relations anatomically to the auditory system and its role in auditory discrimination remains to be discovered in other mammals The identification of such a region in the monkey or other primate will be of particular interest

The cursory review which I have given of experimental studies of the auditory cortex is sufficient, I hope, to indicate that the so-called auditory cortex is not a unitary region, whether considered from the standpoint of its structural relationships or of its function We have a reasonable amount of knowledge about the afferent projections of the auditory system to the subdivisions of this region, we know very little, however, about its connections with other systems, *e g*, with the unspecific afferent systems, with the limbic system, and with the recurrent or efferent auditory system to which our attention has been called by the experiments of Grant Rasmussen[18, 19, 20]

In my opinion, we have made considerable progress in understanding something of the role of the total auditory region in sensory discrimination, but our analysis of the functions of the sub-areas is only beginning This must be kept in mind when considering the relationship between the results of experimental studies and clinical studies of man In the latter, complete bilateral destruction of auditory projection areas probably never occurs Lesions produced by accident, disease or surgery are not likely to be confined to any one subdivision, nor even to auditory cortex, and the exact locus of the lesion can seldom be determined by post-mortem examination, nevertheless, if experimental studies of animals are extended in directions such as I have suggested, and, if use is made in the clinic of tests which measure functions similar to those which can be tested in lower animals, a gradual and profitable integration of findings from research in the experimental laboratory and in the clinic should be possible

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DISCUSSION OF FUNCTION OF AUDITORY CORTEX †

Archie R Tunturi,

University of Oregon,

Portland, Ore

INTRODUCTION

A decade ago you would not have believed what has been presented today concerning the auditory system, and the auditory cortex in particular This modern research into the auditory system was initiated by the Office of Naval Research, to whom we owe a special debt for the contributions which

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you have heard. Dewey Neff has presented an outstanding review of the research on the auditory cortex which presents many problems, and their solutions are slow in being realized. Bit by bit the knowledge of the anatomy and physiology of the auditory cortex is accumulating, so that we have now a more advanced understanding of this region of the brain, however a serious need is a discipline which will permit a break through into the function of the auditory cortex, and more generally into the function of the brain as a whole. We would like to hope that this discipline is attainable within the next decade. The need for knowledge of how the brain functions is important, not only to the understanding of the relation of the auditory cortex to speech perception and hearing but also to an understanding of the brain in neurological and mental diseases. I believe that you will agree with me after listening to these excellent papers today, that the audiometer after all tests but a tiny portion of our hearing.

We are indebted for our knowledge of the minute anatomy of the nerve cells in the auditory cortex to Cajal[2] and Lorente de No,[3] who have applied the Golgi silver techniques to unravel the temporal region. The nerve cells in the auditory cortex are so densely packed that the detailed course of the individual nerve connections cell by cell is still practically unattainable. The nerve fibers from the medial geniculate body to the cortex have been explored grossly by retrograde degeneration techniques. Some facts are known of the nerve fibers arising from the other parts of the brain and terminating in the auditory cortex. Brodman's[1] parceling of the cerebral cortex into areas has proved of doubtful value to the modern neurophysiologist.

Physiological studies have led to more precise location of the projections from the geniculate body upon the cortex, and in particular the detail within these connections.[6 7 8 9 10 11] We have data on the time it requires nerve impulses to travel from ear to cortex, the distribution of responses over the surface, and the cell layers where the responses arise. In ablation experiments performed on various animals we are faced with the surprising fact that surgical lesions of the auditory cortex produce little effect on conditioned reflexes.[12] Removal of the auditory cortex causes no change in the threshold of hearing, multiple conditioned reflexes are not affected, but Dewey[15] has presented evidence for disturbances in conditioned reflexes to temporal aspects of stimuli The search for psychological correlates of hearing has been in vain Evidence for space localization of sounds, pitch discrimination or difference limens of intensity or pitch has not been found Perhaps there is some evidence for a loudness function

Thus far we have failed to implicate the auditory cortex with a specific function Let us consider more closely the meaning of function We all like to apply the term function in terms of our own behavior, or something that we can grasp simply Suppose in this case we consider the function in terms of the central nervous system With this in mind, let us examine certain stable properties of the auditory cortex that do not change under various conditions One such property is the frequency localization in which a response to a particular frequency of a sound always occurs in the same location[13] The spacing between the foci of response is constant, giving us what might be called a frequency map of the auditory cortex The time of arrival as well as the time course of the responses remain constant The masking of the cortical responses by means of steady tones or noise is extremely stable and accurately measureable[14] The masking data from the cortex are not unlike the results obtained in human subjects The threshold curve at the auditory cortex, even under anesthesia, is identical to the normal thresholds of human hearing Other constant properties are the refractory period, the absence of contralateral masking, the excitation of a strip of cortex at one intensity for one ear but not the other, and the refractory period between responses due to sounds delivered to the opposite ears

How the auditory cortex functions must be based upon the structural and physiological properties that remain stable The nervous system does not hear what is occurring at the ear, but only the electrical activity in the nerve cells of the pathways and the auditory cortex. It is a necessary premise that our acoustical environment must be represented in a reasonable form in the central nervous system, a conclusion not unlike that of Locke, Berkley and Hume, that our external world is limited to our own central nervous system Our interests in stable properties is that they alone can form the representations of the external environment The representations form a copy of the acoustical world, and it is with this copy that the nervous system must concern itself If the copy is not stable nothing would be known of the external world Since we are dealing with copies or representations, albeit in coded form, we are most certainly dealing with communication

In our study of these copies of our external environment, a region has been found in which after much simplification there exists a memory for over one-and-a-half billion different sounds,[15] a memory lasting as much as 200 times the duration of sound itself This portion of the auditory cortex is no longer than three-quarters inch and no wider than one-half inch Yet to this region of the brain no psychological correlate, nor function in terms of behavior, has been assignable

What then is the function of this area to the nervous system itself? What we would like to do is study the effects of the area on messages or information By studying the relation of acoustical signals to the representations it has become possible to establish a mathematical formulation of the communication aspects of the auditory cortex This allows up to compute the amount of information received at the auditory cortex in various sounds, therefore, might not communication theory be the discipline we need to understand the function of the brain? After all, the brain uses up more information than any other substance None of us would believe that the mind consists of mitochondria, proteins, sugars, acetylcholine, choline esterases or other enzymes These materials are like the junction of two metals to a transistor, or what oil is to a relay, but have no bearing on the information handled by such devices Needless to say the brain has been compared to computers, but in many ways it has properties different from these mechanisms I, therefore, ask you to watch the developments in information theory toward a solution of the problem of the brain

Study of the anatomy and physiology of the auditory cortex has uncovered a multitude of new facts during the last decade concerning its structure and performance Conditioned reflex studies have ruled out many possible functions of the area but have suggested other ones What is needed is a new discipline or scientific method which will give us the answer to the function of the brain Such a method we feel is very likely available in communication theory

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FUNCTION OF THE AUDITORY CORTEX
CLINICAL DISCUSSION (NEUROSURGERY)

ROBERT B. KING,*
State University of New York,
Syracuse, N. Y.

In discussing the functions of the auditory cortex from a clinical standpoint, a subject so ably presented by Dr. Neff in "Parameters of controlled physiological investigation," I must confess that little definitive clinical work has been undertaken. There are, however, many areas of mutual concern to physiologist, anatomist, physicist and physician, indeed, even surgeon. As Dr. Neff has said, there is often a 5 to 10 year gap between concepts of function demonstrated in laboratory environs and their initial adaptation for clinical use. A major challenge to all of us must be to absorb this time deficit by earlier synthesis of laboratory analysis, and thereby to gain understanding of non-clinical investigative findings which are of clinical consequence. Clinical perplexities, however, examined in the arena of the investigator, will yield fruitful avenues for investigation of fundamental mechanisms in anatomy, physiology and psychiatry. The interchange of experience should be mutual.

Recent and current studies of auditory cortex with parameters of neurophysiology and psychology have been discussed today. Although clinical efforts to understand the functioning of auditory cortex in more than broad and general terms have had a late beginning, yet three avenues of clinical study are of current interest.

Detailed examination of discrimination functions have been reported by Bocca, and were discussed in detail yesterday.

In a similar vein, discriminative functions have also been studied in six patients with infantile hemiplegia before and after hemispherectomy.

1. Pure tone audiograms were normal. A list of spondees was presented to each ear of these patients, and threshold intensity established for the correct identification of 50 per cent of these bisyllabic words. At 70 db above this threshold, then, two series of monosyllabic test words were delivered separately to each ear. A distinct discrepancy between the left and right was clearly evident in such testing of discriminatory function. Forty-five per cent of test words delivered to the ear contralateral to the abnormal hemisphere were incorrectly identified, while 20 per cent of the words so delivered to the ear contralateral to the more normal hemisphere were not repeated correctly. This 20 per cent may indicate a wide variation of normal related to the relatively normal hemisphere.

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*Formerly at Washington University St. Louis Mo.

Although the post op E.E.G. in this hemisphere became more normal, and there was improvement in seizures and behavior disorders in these patients, there was no improvement in their postoperative discrimination scores. This persisting deficit suggests that nociferous cortex of the abnormal hemisphere was not contributing materially to the deficit inferred for the more normal hemisphere. It may be that this degree of abnormality represents the maximum potential for discrimination of a single hemisphere. Further experience with such testing techniques as these may well yield useful methods for better clinical understanding of focal cortical lesions of auditory and related association cortex.

A second avenue of clinical investigation has been that which Penfield and his co-workers[2] have explored. The stimulation of abnormal cortex with patients under local anesthesia may initiate an auditory experience. Tinnitis may be reported with stimulation of the superior temporal gyrus. From neighboring regions, complex, and at times prolonged auditory sequences, songs or even symphonic orchestrations, may be reported by the patient. In this circumstance, however, a combination of memory and recall of auditory events add to the complexity of the analysis. Although the stimulus in such a circumstance as this is quite an artificial one, the experience described by patients may be realistic in many details.

There has been no extensive study of the electrophysiologic

FUNCTION OF THE AUDITORY CORTEX
CLINICAL DISCUSSION (NEUROSURGERY)

ROBERT B KING,*
State University of New York,
Syracuse, N Y

In discussing the functions of the auditory cortex from a clinical standpoint, a subject so ably presented by Dr Neff in "Parameters of controlled physiological investigation," I must confess that little definitive clinical work has been undertaken There are, however, many areas of mutual concern to physiologist, anatomist, physicist and physician, indeed, even surgeon As Dr Neff has said, there is often a 5 to 10 year gap between concepts of function demonstrated in laboratory environs and their initial adaptation for clinical use A major challenge to all of us must be to absorb this time deficit by earlier synthesis of laboratory analysis, and thereby to gain understanding of non-clinical investigative findings which are of clinical consequence Clinical perplexities, however, examined in the arena of the investigator, will yield fruitful avenues for investigation of fundamental mechanisms in anatomy, physiology and psychiatry The interchange of experience should be mutual

Recent and current studies of auditory cortex with parameters of neurophysiology and psychology have been discussed today Although clinical efforts to understand the functioning of auditory cortex in more than broad and general terms have had a late beginning, yet three avenues of clinical study are of current interest

Detailed examination of discrimination functions have been reported by Bocca, and were discussed in detail yesterday

In a similar vein, discriminative functions have also been studied in six patients with infantile hemiplegia before and after hemispherectomy

1 Pure tone audiograms were normal A list of spondees the next two slides The first (see Fig 2) illustrates evoked radiation responses from frontal association cortex (as in Fig 1B) with repetitive stimulation (A—6/sec B—10/sec., C—20/sec , D—50/sec., and E—50/sec) using DC amplifiers Note the negative shift in steady potential with increasing frequency of stimuli, and the persistence of this shift after terminating the stimulus

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*Formerly at Washington University St Louis Mo

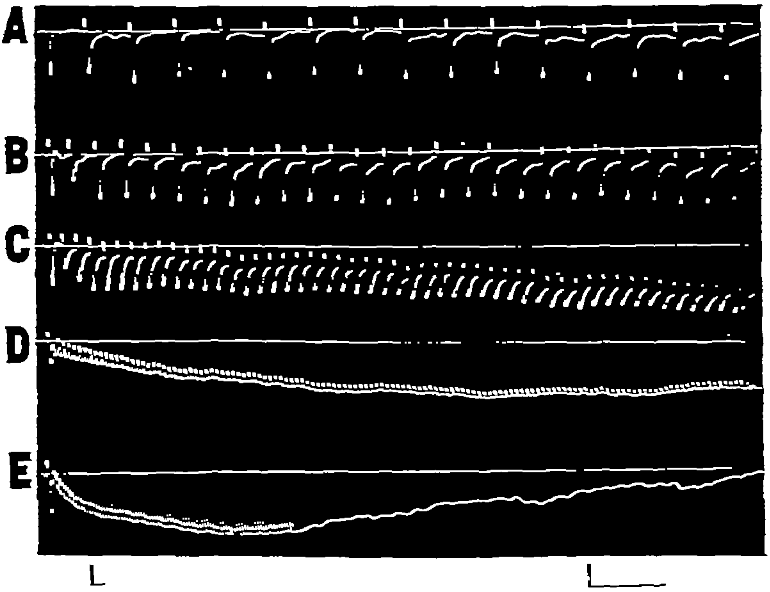

Fig. 2 Right angle at right calibration for E-500 V and 1 sec. Right angle at left is calibration for A-D 50 V and 20 msec.

Similar repetitive stimulation of subcortical white matter of the superior temporal gyrus (see Fig 3) shows further changes not seen in recordings from frontal association cortex. The increasing complexity of this response is apparent as the frequency of stimulation increases (B—6/sec., C—10/sec., D—20/sec., E—50/sec., F—100/sec.) In "B" and "C" a negative shift similar to that shown in Fig 2 for frontal association cortex is apparent, but in "D," "E," and "F," an early positive shift of the base is the dominant change returning to the original base line. The negative shift persists after the period of stimulation at lower frequencies potentials evoked by such stimuli in man A third avenue of investigation then is being explored Single and multiple evoked responses of human cortex are being studied and will be reported at a later date[3] Such evoked potentials indicate that there may be a number of regional variables in human cortex which do not appear in studies of other cortex

Fig 1 illustrates evoked potentials from human frontal association cortex and from the superior temporal gyrus A calomel cell recording electrode on the pia was recorded

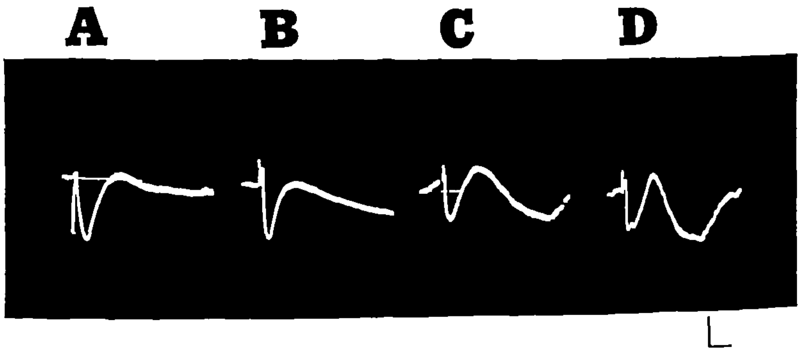

Fig 1 Calibration angle 500 V 20 msec

against a remote electrode Stimuli for "A" were delivered at the surface 3 mm from the recording electrode The potential indicates a pure dendritic response Stimuli for "B" were delivered at the subcortical white matter of the same gyrus just below the surface recording electrode (radiation response) In "C" the stimulus was applied to subcortical white matter of the adjacent gyrus activating "U" fibers The surface of the superior temporal gyrus was recorded in "D," while stimulating adjacent white matter (radiation response) The response in "B" and "D" are then analogous The increased complexity of the potential form in the later instance is apparent The prolonged late negative deflection in "D" has not been seen in records taken from a limited number of other cortical regions

Further comparison of the evoked cortical response in frontal and temporal association areas can be illustrated in the next two slides The first (see Fig 2) illustrates evoked radiation responses from frontal association cortex (as in Fig 1B) with repetitive stimulation (A—6/sec , B—10/sec , C—20/sec , D—50/sec , and E—50/sec) using DC amplifiers Note the negative shift in steady potential with increasing frequency of stimuli, and the persistence of this shift after terminating the stimulus

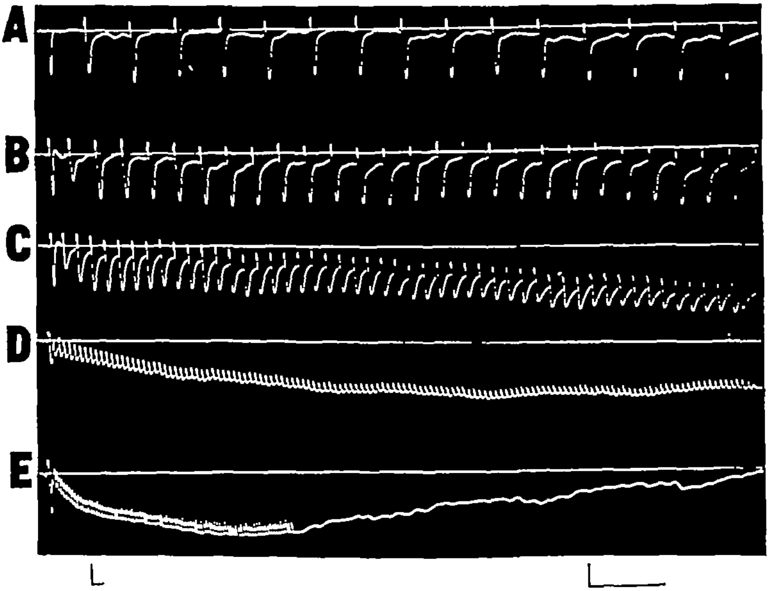

Fig 2 Right angle at right calibration for E 500, V and 1 sec Right angle at left is calibration for A D 50 V and 20 msec

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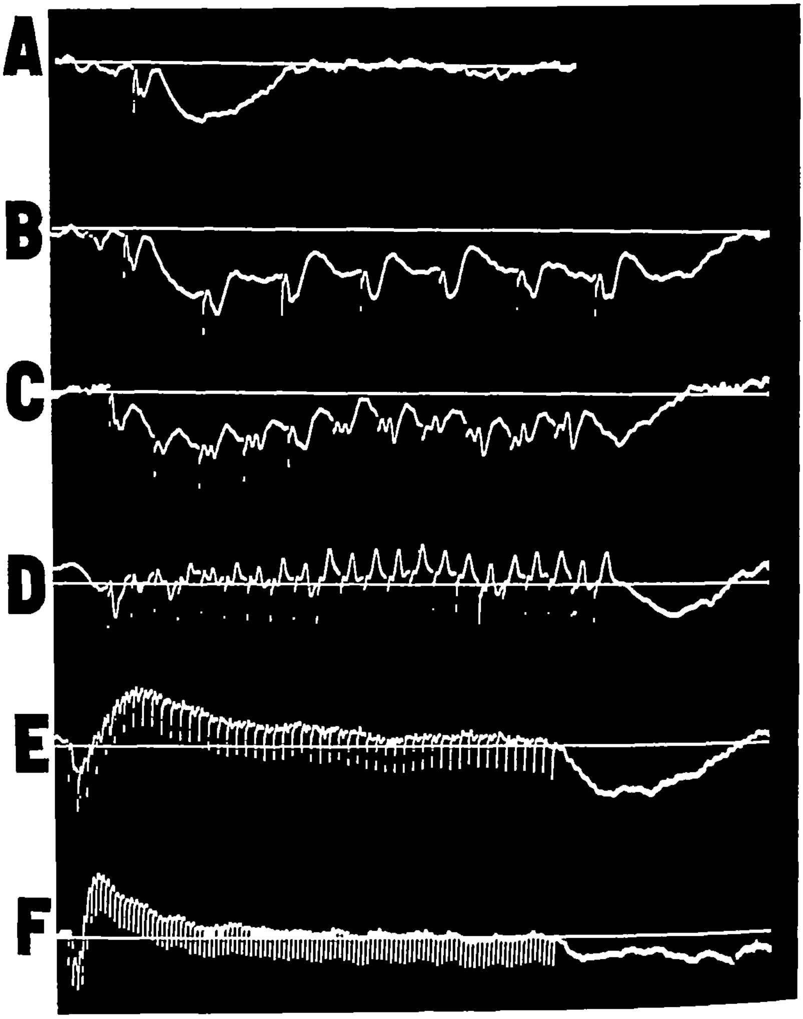

Fig 3 Vertical calibration 500 V Horizontal calibration 20 msec

A detailed analysis of these evoked cortical potentials is not warranted at present Many more records must be acquired before a synthesis, based on such an analysis, can have meaning in terms of the functioning of neural components of frontal and temporal association cortex This third avenue of clinical investigation has only recently been followed and must be further explored

In summary, I have tried to indicate three avenues for clinical investigation of the functioning of auditory cortex which have shown some promise of extending our knowledge of these regions

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PERCEPTIVE HEARING LOSS *

HAROLD F SCHUKNECHT,

Henry Ford Hospital,

Detroit, Mich

In recent years much investigation has been directed toward the physical and bioelectric mechanisms by which the cochlea receives the sound stimulus and codes it into neural impulses Our knowledge of the auditory physiology beyond the cochlea is less well known Future research in this area will be concerned with the mechanisms by which neural patterns are decoded and integrated with established memory patterns and other information, to result in hearing as we experience it

THE HUMAN AUDITORY CORTEX

The human cerebral cortex has been mapped according to minor variations in the pattern of the grey matter[1,2,3] The auditory cortex of man is located in the superior temporal gyrus along the sylvian fissure, which corresponds to the topographic areas 41, 42 and 22 of Brodmann (see Fig 1)

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*Perceptive hearing loss here refers to that type due to disorders of the auditory pathways and cortex which is in accordance with the recent terminology suggested by the Committee for Conservation of Hearing of the American Academy of Ophthalmology and Otolaryngology

Campbell has further divided this area into an audito-sensory region (area 41, thought to be related mainly to auditory perception) and an audito-psychic region (areas 42 and 22, thought to be important for auditory memory) These concepts, however, do not justify thinking of these areas as discrete functional units

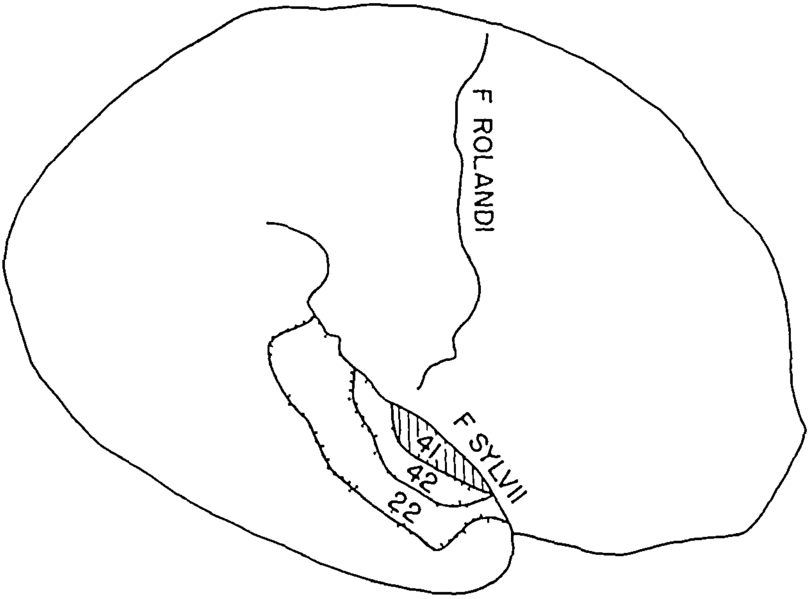


Fig 1 Auditory cortex of man as determined by cyto-architectonic studies Shown are areas 41 42 and 22 of Brodmann and the audito-sensory (ruled) and audito-psychic (stippled) areas of Campbell

Further evidence regarding the auditory cortex of man comes from the investigations of Penfield and Rasmussen,[4] who electrically stimulated the auditory cortex of humans during the course of intracranial operations Local anesthesia was used, and the patients were asked to relate their auditory experiences

Some of the sensations reported by the patients are listed below

Ringing sound like doorbell
Humming sound
Low-pitched sound like a motor

Continuous "clicking," like crickets at night
Change in the sound of your voice
Rushing sound, like a bird flying
Contralateral ear felt as though she could not hear out of it
Noise like birds chirping
I hear funny things
I hear "boom boom" on something
Buzzing in contralateral ear
Key of your voice changed
I am a little deaf

The records from these patients did not lend themselves to statistical study or detailed analysis, however, the investigators made the following observations

1 *Auditory responses were more numerous in the audito-psychic area* of Campbell (areas 42 and 22 of Brodmann), and less frequent in the audito-sensory area (area 41 of Brodmann)

2 Electrical stimulation of the temporal lobe resulted in the sensation of sound in some patients and the sensation of being deaf in others, therefore, stimulation seemed to paralyze as well as activate

3 The auditory sensations were most often referred to the contralateral ear

4 Electrical stimulation close to the margins of the sylvian fissure were more apt to produce simple tones, ringing, etc, while stimulation away from the fissure was more apt to introduce an element of interpretation of the sound

They also made a very interesting observation in patients having psychical seizures, the latter being described as a purely psychical state characterized by sudden change in perception of environment, a sort of dream state Several patients having visual or auditory hallucinations in their psychic state experienced these phenomena when the temporal cortex was electrically stimulated Apparently in these patients the cortex previously had been activated or conditioned by recurrent epileptic discharges, so that electrical stimulation resulted in activation of acquired patterns of neural flow, in other words, the memory pathways

LESIONS OF THE TEMPORAL LOBE

The possible effect of unilateral temporal lobe tumors on hearing has interested clinicians for some time, but because hearing tests were lacking in quantitative values no consistent pattern of auditory loss was established for temporal lobe lesions[5,5-8] Although bilateral temporal lobe lesions are less common, they can exist in Pick's disease and in cerebrovascular disorders, and in such cases the observers have consistently reported a total bilateral hearing loss[5,9,10,11] With the development of electronic equipment, which permitted standardized audiometric evaluations, many new psychoacoustic phenomena have become manifest One of the phenomena pertinent to this discussion only recently established is the loss of auditory intelligibility which accompanies temporal lobe tumor This observation was slow in developing because the discrimination defect did not register in commonly used discrimination tests but became manifest only when a more difficult test was imposed upon the auditory system

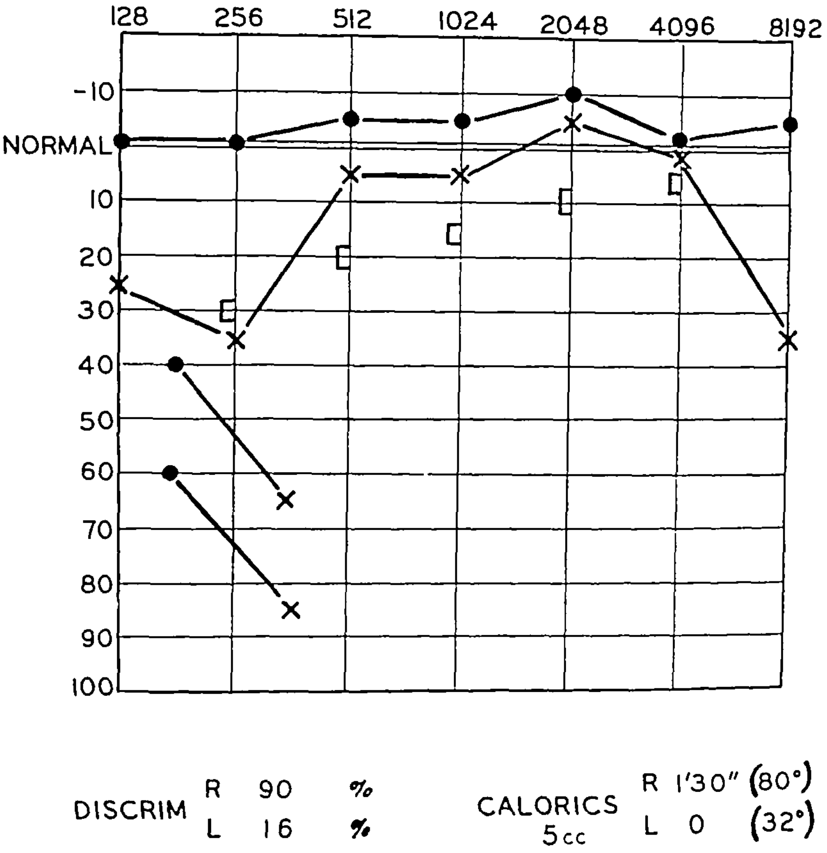
Apparently the amount of auditory information which is provided with each phoneme in normal speech is in excess to that which is necessary for intelligibility and, therefore, mild degrees of receptive aphasia (loss of auditory intelligibility) can exist without being detected by standard discrimination tests Bocca, et al ,[12] and Pietrantoni, et al ,[13] have shown, however, that if a patient with a temporal lobe tumor is given a more difficult discrimination test, consisting of distorted speech (accelerating, interrupting, limiting frequency range, delivering in noise), the intelligibility is decreased in the ear contralateral to the temporal lobe lesion Goldstein, et al ,[14] also have observed this phenomenon in patients with infantile hemiplegia

Patients so afflicted are unable to understand the spoken language in spite of normal auditory acuity Sounds reaching the ears of these patients are transmitted along the auditory pathways, but have no meaning Perceptive aphasia appears to be a true entity and is thought to result from aplasia, mal-development or trauma to the auditory cortex. Further proof is needed, however, to establish firmly the concept that auditory aphasia is the manifestation of a temporal lobe cortical deficit. A similar disorder, termed auditory imperception, is characterized by an ability to understand speech and develop language with auditory training, but difficulty in interpreting auditory tests involving discriminatory responses.[15] Derbyshire, et al.,[16] have shown that under favorable conditions auditory responses can be recorded in electroencephalograms of humans, and that the method can be used as an objective test of hearing. According to Rosenblith[17] it may be possible to develop that method into a practical clinical tool through the use of an electronic computer, which will sift the auditory response out of random background cortical activity. A serious limitation of objective auditory tests, of course, is that they do not tell us whether the responses reflect useful organized auditory information.

DECREASE IN NEURONE POPULATION

Neff and associates[18] have shown that after bilateral ablation of the auditory cortex in cats, the pure-tone threshold is preserved, but more complicated discriminations, such as localization of sound and pitch discrimination, appear to be altered. The combination of circumstances in which there is a discrimination loss out of proportion to the change in pure-tone thresholds is not unique for cortical lesions, for it is also present when the first order neurone is partially destroyed by acoustic neurinoma, as was first pointed out by Woellner and myself in 1953,[19] and subsequently by Liden[20] and Walsh and Goodman[21] and Goodman.[22] (see Fig. 2)

The deafness of aging (presbycusis) also is often characterized by discrimination loss out of proportion to the pure-tone threshold loss (see Fig. 3). It has already been shown that the presbycusic ear often suffers greater degeneration of the cochlear nerve than of the corresponding organ of Corti[23, 24, 25] (see Fig. 4). In the aged person the neurone population at higher levels in the auditory system may also be decreased,



WACHOWIAK

Fig 2 Audiometric and vestibular tests of patient with left acoustic neurinoma proven subsequently at operation In the left ear the pure-tone thresholds for the three speech frequencies (500 1000 and 2000) were near normal however the speech discrimination score was only 16 per cent on repeated tests (PB-Max Rush Hughes recorded word list)

for it is well established that the aging brain suffers a diffuse neuronal degeneration

The auditory manifestations in patients with temporal lobe lesions, acoustic neurinoma and presbycusis, suggest that lesions involving the auditory pathways result in a system that transmits simple signals of threshold magnitude (such as pure tones) but cannot handle the complex signals of speech

Woellner and I designed an experiment in which we further tested the concept that partial loss of fibers at the level of

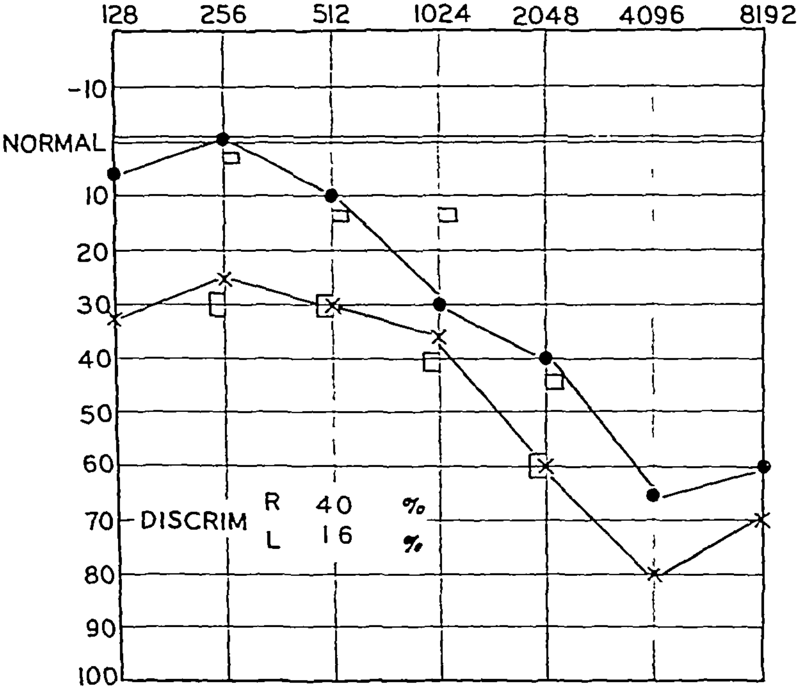
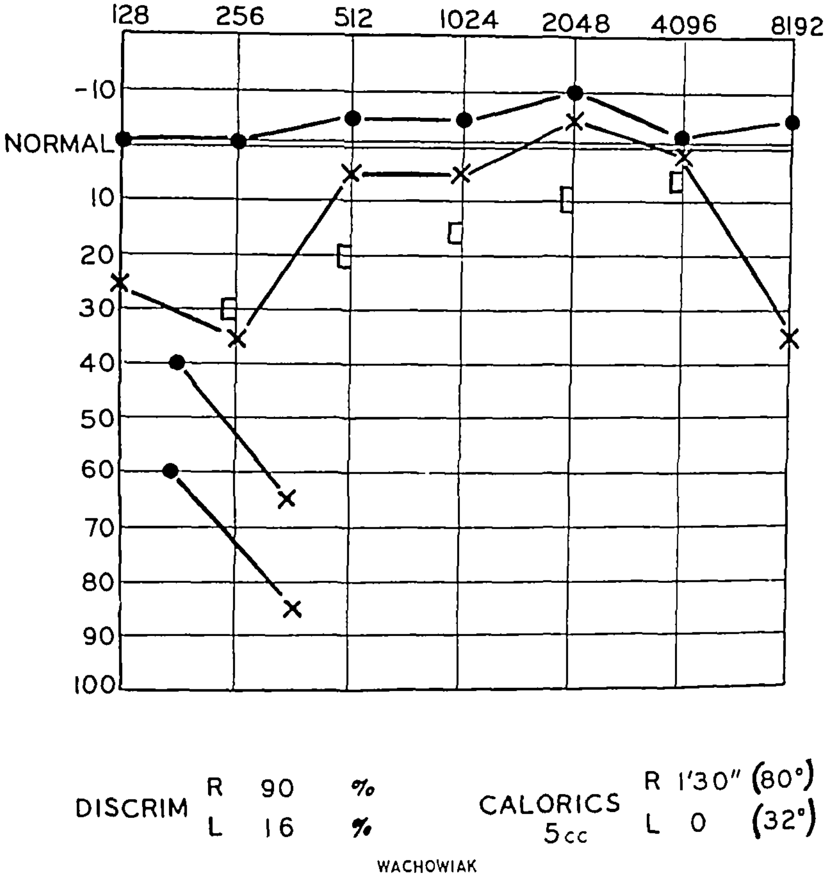


Fig 3 Audiometric findings of 70-year-old man with presbycusis showing discrimination loss out of proportion to loss for pure tones (PB-Max. live monitored voice)

the first order neurone is consistent with normal pure-tone thresholds Working with conditioned cats we found that 75 per cent of the acoustic nerve fibers could be lost by actual count without creating a hearing loss for pure tones[26] (see Fig 5)

COMMUNICATION THEORY

In recent years concepts of information-transmission have been expressed in precise mathematical terms Although few of us are capable of understanding the mathematics involved, we readily appreciate its importance for auditory intelligibility, the ear analyses speech by recoding the sound signals into impulses which travel up the auditory nerve We know that the fundamental coding mechanism is very simple, and that a nerve impulse is either present or absent



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This principle of "all or none" is basic to nerve physiology Other limitations are that a single nerve fiber will carry a maximum of only 800 to 1000 impulses per second We may enumerate the variables in a neurone pattern as follows *1* Frequency of impulses in a single fiber (below 1000 c p s), *2* time relation between impulses in the various fibers, *3* selectivity as to which fibers are being activated, *4* the number of fibers being activated In spite of the "all or none" law, the cochlear nerve can carry all of the information required for intelligibility of the spoken voice This is possible because of the tremendous number of channels in this communication system, for we know there are about 35,000 channels, or fibers, in the human cochlear nerve In a pathological auditory pathway with a loss of nerve fibers, a limitation is imposed upon the coding mechanism, and the amount of information which can be transmitted from the ear to the brain is less than normal

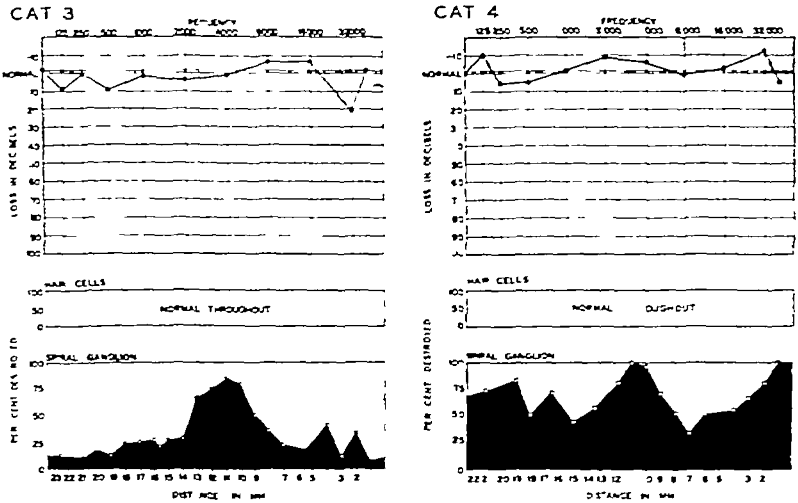

Fig 5 Behavioral audiograms and cochlear charts for two animals with partial section of the cochlear nerve The frequencies are placed along the abscissa of the audiogram in accordance with their anatomical distribution along the cochlear duct. The abscissa of the cochlear chart indicates millimeters along the cochlear duct as measured from the basal end and the black filling shows per cent of ganglion cells lost as determined by actual count Note that for Cat 2 there is an average loss of about 75 per cent of ganglion cells but pure-tone thresholds remained normal

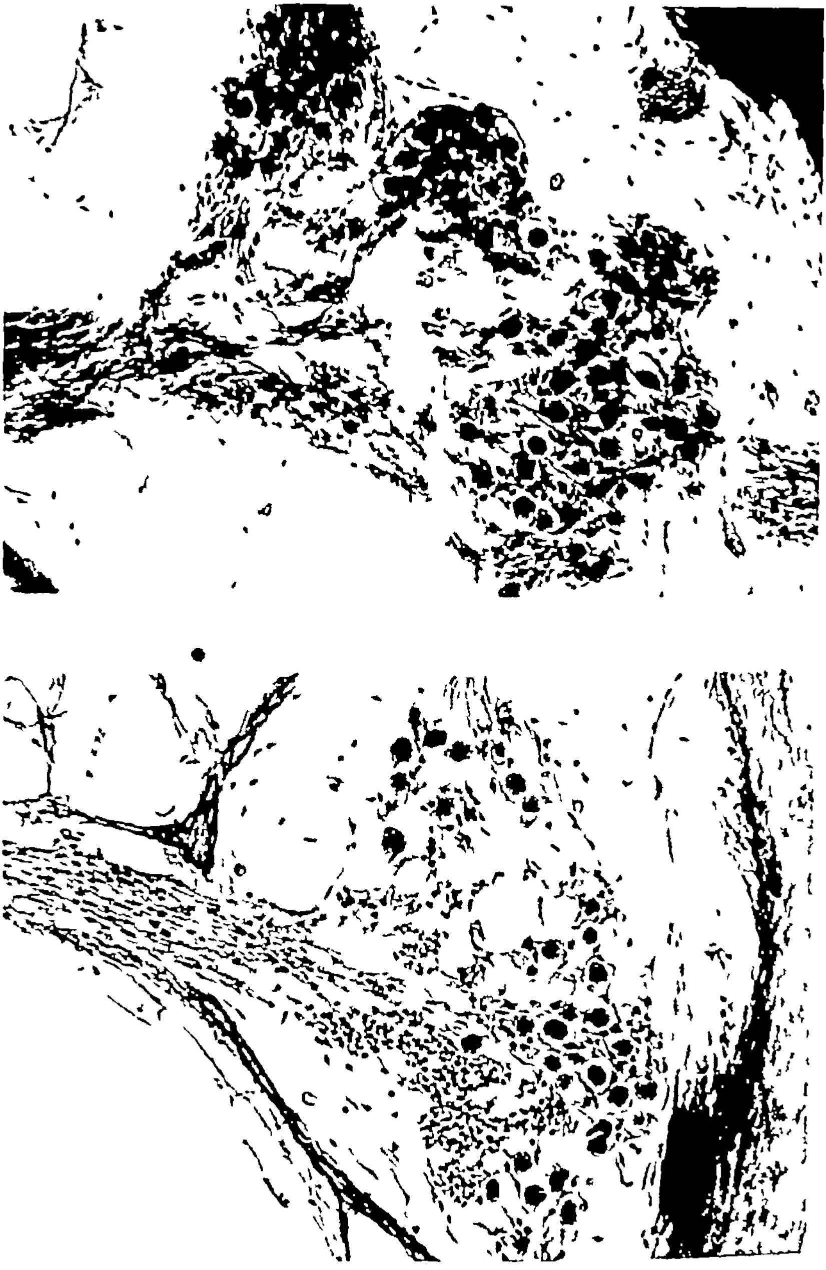

Fig 4 Photomicrographs of spiral ganglion of normal young person (above) and 70-year-old man (below) both views from the upper basal turn The aged man had severe degeneration of the organ of Corti and spiral ganglion in the lower basal turn accounting for a high tone deafness In the upper basal turn the organ of Corti was normal but there was a loss of 30 per cent to 50 per cent of the spiral ganglia It is this loss of neurone population which probably accounts for the deteriorating auditory discrimination (phonemic regression) in the aged

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CONCLUSIONS

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13 Pietrantoni, L, Bocca, E and Agazzi, C 'Diagnose delle Sordita Retroccocleari Idos" Milano, 1956

14 Goldstein R, Goodman, A, and King, R Hearing and Speech in Infantile Hemiplegia Before and After Left Hemispherectomy *Neurol*, 6 869, 1956

15 Hardy, W Personal communication

16 Derbyshire, A G Fraser A A, McDermott, M, and Bridge, A Audiometric Measurements by Electroencephalography *E E G and Clin Neurophys*, 8 467 1956

ancient method now, but it was a popular technique then About 1930 the first sound level meters were introduced Because the users soon found that many sounds gave the same reading on the meters but did not sound the same, an effort was made to approximate the characteristics of the ear This effort was unsuccessful, but the results of it remain with us as the A, B, and C scales of modern instruments

It soon became clear that some sort of frequency analysis was necessary Various narrow-band analyzers were developed, but their use was limited because of the tedious nature of the measurement The more modern octave band analyzer strikes a happy medium between detailed frequency analysis and ease of measurement It has been used extensively in the past decade, and most industrial noise data are today being reported in octave bands Recently, fractional octave bands have appeared but do not, to date, enjoy widespread use because of the added complexity of reporting the data

Until a few years ago sound pressure level and frequency were the primary parameters involved in noise measurement All measurements were essentially cross-sections in time Very little attention was paid to the fluctuations and variations of the noise as time passed An excellent compilation of industrial noise measurements of this type has been prepared by Karplus and Bonvallet, (*American Industrial Hygiene Association Quarterly,* Vol 14, page 235, 1953), however, measurements of this sort can only be related to impairment of hearing when the exposure is steady throughout the working day, and the noise has no unusual transient characteristics

Since the relations of noise to hearing loss are of great importance in the field of industrial noise, more emphasis has been placed in recent years upon the design of instruments that give information about the transient character of the noises The impact meter, developed by General Radio, and the exposure meter, developed by Crouch, are two examples of this trend toward instruments that are aimed at the measurement of the time-varying characteristics of noise Research sponsored by the Armed Forces has also been di-

THURSDAY MORNING SESSION,

May 16, 1957

HEARING LOSS AND NOISE EXPOSURE

The International Conference on Audiology convened at 9 30 A M , in the Auditorium of the Washington University School of Medicine, St Louis, Missouri, Prof Walter A Rosenblith, Associate Professor of Communications Biophysics, Massachusetts Institute of Technology, Cambridge, Massachusetts, presiding

DR IRA J HIRSH, (St Louis, Missouri) Unfortunately, Dr Kenneth Day could not be with us, and Prof Walter A Rosenblith has consented to act as chairman for this session

NOISE IN INDUSTRY

JEROME R COX, JR ,

Central Institute for the Deaf,

St Louis, Missouri

This is a report on some noise measurements that were made in a number of factories in a certain section of the United States These measurements were directed towards evaluating individual noise exposures The goal of the survey was some statistical indication of the industrial noise exposures in a section of the country Before presenting the procedure for the survey and the results, I will give a brief review of noise measurements in the United States

In 1925, noise measurements were made in the City of New York, with the aid of the 3-A audiometer, an early Western Electric instrument The masking produced by the noise was measured by the audiometer The sound pressure levels were then calculated from the masking This seems like an

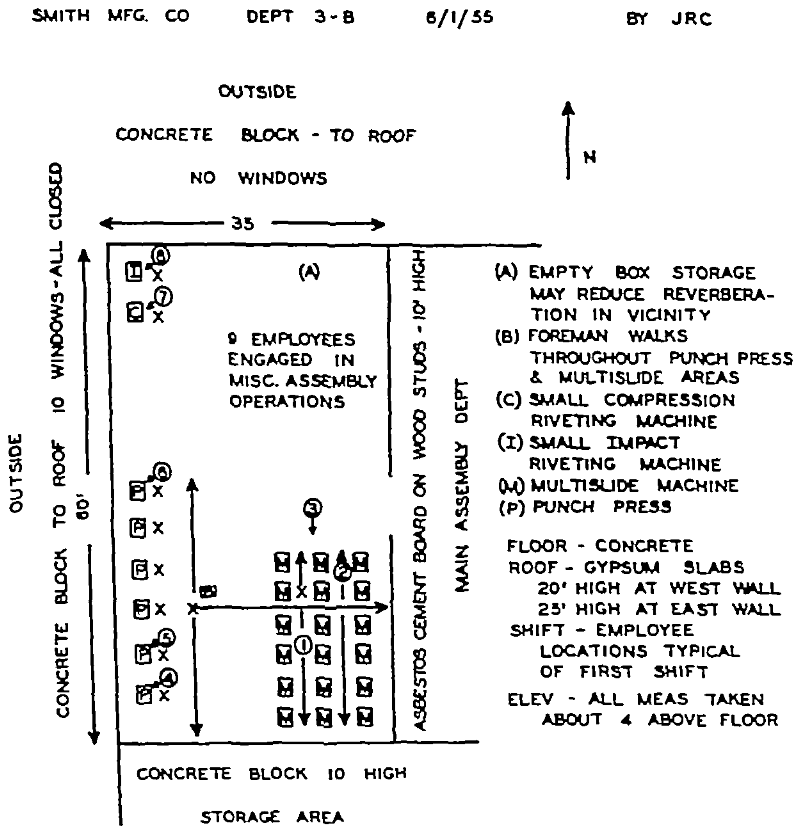

SMITH MFG. CO
DEPT 3-B
8/1/55
BY JRC
OUTSIDE
CONCRETE BLOCK - TO ROOF
NO WINDOWS
N
35
80'
OUTSIDE
CONCRETE BLOCK TO ROOF 10 WINDOWS - ALL CLOSED
ASBESTOS CEMENT BOARD ON WOOD STUDS - 10' HIGH
MAIN ASSEMBLY DEPT
(A)
9 EMPLOYEES ENGAGED IN MISC. ASSEMBLY OPERATIONS
(A) EMPTY BOX STORAGE MAY REDUCE REVERBERATION IN VICINITY
(B) FOREMAN WALKS THROUGHOUT PUNCH PRESS & MULTISLIDE AREAS
(C) SMALL COMPRESSION RIVETING MACHINE
(I) SMALL IMPACT RIVETING MACHINE
(M) MULTISLIDE MACHINE
(P) PUNCH PRESS
FLOOR - CONCRETE
ROOF - GYPSUM SLABS 20' HIGH AT WEST WALL 25' HIGH AT EAST WALL
SHIFT - EMPLOYEE LOCATIONS TYPICAL OF FIRST SHIFT
ELEV - ALL MEAS TAKEN ABOUT 4' ABOVE FLOOR
CONCRETE BLOCK 10' HIGH
STORAGE AREA
①
②
③
④
⑤
⑥
⑦
⑧

Fig 1 Typical floor plan of department surveyed All significant noise sources in this small shop are identified working areas of employees are indicated by crosses and each measuring station is marked by a circled number

industry and the number of employees, shifts, breaks in the daily exposure, and other departmental information The fundamental framework for reporting our data is shown in Fig 1

This is a drawing typical of the departments surveyed This is the floor plan of a small shop, showing all the significant noise sources, the location of all the workers, the location of each of the measuring stations, and, in addition, information about the acoustical environment and movements of employees who do not remain in a fixed position rected toward the measurement of noise exposure rather than the simple frequency distribution that was so popular during the past decade

I think the concept of a noise exposure is one of the important developments in the field of industrial noise It is usually assumed that time and intensity are equally important in determining the noise exposure A quantitative way to state this assumption is to say that sound energy, the product of time and intensity, is proportional to the noise exposure, and, therefore, directly related to the hearing loss that may result from the exposure Students of physics will recall that the product of time and intensity is energy—in this case sound energy

In computing sound energy, intensity is expressed in watts per unit area rather than in decibels, a logarithmic unit Translated into decibels, the energy rule means that a noise present throughout an eight-hour working day would be equivalent to a similar noise that is present during one-half the working day, but three decibels more intense Similarly, a noise present only one-tenth of the working day is equivalent to a noise ten decibels less intense, but present throughout the working day The assumption that noise exposure is proportional to the sound energy received by the ear has not been adequately validated It is a frequent assumption, and I will make no attempt to justify it

In order to evaluate noise exposure a tremendous amount of data is necessary It is almost unbelievable to people who have not encountered the problem Data must be taken on the intensity, frequency distribution, transient characteristics, and the daily time pattern of the noise In addition, the workers' movements in the noisy area, and the characteristics of the sound field, must be recorded With these data, it is possible to estimate the noise exposure according to the assumption that exposure is proportional to sound energy In the measurements to be reported, we attempted to gather all of the information necessary for the evaluation of every man's noise exposure in each of the plants surveyed

A general data sheet gave information about the kind of was studied The total number of workers whose exposures were evaluated is just slightly under thirty thousand As you can well imagine, considerable data was accumulated

Because of the scope of the survey, it was necessary that a simple scheme be developed for analysis of the data The following procedure was followed *1* A rough frequency analysis was carried out to estimate the sound pressure level in the 300-600 c p s band This octave was chosen because it is the important sorting octave, according to the data presented in the report of Committee Z 24-X-2 of the American Standards Association (American Standards Association, *The Relations of Hearing Loss to Noise Exposure,* Z 24-X-2 Report New York, 1954) *2* The equivalent exposure level was found by using the assumption that energy is proportional to exposure discussed a few moments ago *3* Appropriate adjustments based on experience with similar machines in other plants must be employed, because quite often data are not as complete as they should be. *4* All of the noise exposures are categorized into the four classifications shown in Fig 3

Classification of Noise Exposure	A	B	C	D
Equivalent Sound Pressure Level in the 300 600 c p s Octave Band	Greater Than 105 db	105 db to 95 db	95 db to 85 db	Less Than 85 db

Fig 3 Classification of noise exposures according to the steady sound pressure level having a total energy each day equal to that in the 300-600 c p s octave of the actual noise

The equivalent sound pressure level shown is in the 300-600 c.p s octave band All of the noise exposures are sorted into these four classifications After obtaining the totals in each classification we were surprised to find fewer A exposures than anticipated Upon re-examining the distribution of industries in the area studied we find a heavy representation of industries having only a few A exposures, therefore, an adjustment of each of the major classifications of industry was made on the basis of the census of manufacturers

Noise measurements were sometimes made with octave bands, but often a simple sound survey meter sufficed because it is faster, less conspicuous, and satisfactory for rough evaluations of noise exposures A rough frequency analysis can be made from readings taken on the three scales, A, B, and C, of the survey meter (J R Cox, Jr , Approximate frequency analysis from weighting-network data in acoustic measurements *General Radio Experimenter*, Vol 28, p 1, 1953) This scheme worked because of the statistical nature of the survey, but cannot be generally recommended

Location No	Meter Readings (db) A B C	REMARKS
8	98 98 98	1 A small riveting machine Connector is held on anvil and hammer sets rivet Repeated impact 2 About 300 blows/min Operator makes 12 parts/min 3 Sound of hammer striking small part No other source of noise 4 Each rivet takes 5 10 sec 4 bursts/part Machine in use when compression riveting is behind schedule Foreman estimates that this occurs about 25% of the time Operator is otherwise unexposed

Fig 2 A small section of the form used to report data from each of the measurements stations The four items at the right describe the noisy machine its operating conditions the nature of the noise and the noise exposure pattern The number at the left refers to the location of the measurement shown on Fig 1

Figure 2 shows a small section of the form used to report data from each measurement station At the right we see four items the nature of the noisy machine, the operating conditions of the machine, the nature of the noise from the machine in terms of some more familiar noise, and the noise exposure pattern In this example the machine is on only about twenty-five per cent of the time

The survey covered a total of seventy-five plants in twelve different classifications used by the Census Bureau Of the remaining eight, several were not noisy industries, some employ very few people, and one was not found in the area in which this survey was conducted, therefore, it is believed that a sufficiently large variety of noisy industries nation subjected to A exposures were suddenly to incur a 50 db hearing loss, the mean threshold hearing level of the nation would shift by only 0.2 db. This verifies the fact that there must be many other causes of hearing loss. There are others not considered in this study who have serious noise exposures. Many people use firearms extensively in and out of the Armed Services. In addition, there are other kinds of hearing losses that are difficult to differentiate from hearing loss caused by noise.

One final statement that deserves emphasis is: just because a man works in industry is not a sufficient reason to assume that his hearing loss is caused by noise.

HEARING LOSS IN INDUSTRY

Aram Glorig,
William Grings,
Anne Summerfield,

Subcommittee on Noise in Industry,

Los Angeles, Calif.

INTRODUCTION

Valid information about the relations of hearing loss to noise-exposure is difficult to obtain. Undoubtedly, this difficulty is due in part to the complexity of the relations, but there are also many obstacles that must be overcome before we can obtain suitable data from which to draw valid conclusions about these complex relations. It is the purpose of this paper to discuss a recent study of industrial hearing loss as a means of showing some of the difficulties encountered in making inferences from existing audiometric records, to discuss the difficulties generally encountered in field research in hearing, and to describe our attempts to lessen these difficulties.

Two important questions to be answered are: *1.* How much hearing loss results from noise-exposure; *2.* what is the rela-

The total number of workers in noisy industries is shown in Fig 4 The population of the nation at the time of the survey was a hundred and sixty million The total number of people not in schools or hospitals is one hundred and ten million The labor force is sixty-three million, but the labor force in the manufacturing industries is only seventeen million Excluding administrative workers the remainder is fourteen million, of whom only ten million are in industries that have significant noise exposures It is estimated that those ten million workers are distributed among the noise exposures A, B, C, and D, according to the percentages shown in Fig 5

	Millions
U S Population (1953)	160
Non Institutional Population	110
Labor Force	63
Labor Force in Manufacturing	17
Production Workers in Manufacturing	14
Production Workers in Noisy Industries	10

Fig 4 Distribution of the U S population at the time of the survey Noisy industries exclude those that generally have no significant noise exposures anywhere in the industry i e the apparel industry

PERCENTAGE OF PRODUCTION WORKERS IN NOISY INDUSTRY IN VARIOUS NOISE EXPOSURE CLASSIFICATIONS

	A	B	C	D
Percentage	0 5%	4 5%	17%	78%

Fig 5 Estimate of the percentage of workers in noisy industries who are exposed to various noise exposure classifications as defined in Fig 3 Percentages are adjusted from regional survey data to reflect national distribution of noise exposures The Armed Services transportation and construction workers and farmers have been excluded from the survey

One is surprised that the percentage in the A classification is so small Remember, however, that the Armed Services, transportation and construction workers, and farmers have been excluded from the study Only workers in manufacturing industries that have significant noise exposures have been included

In conclusion, there are a few severe noise exposures, but many less severe ones, in fact, if all of the workers in the

The data sampled contains 9,145 audiograms of industrial and flight line personnel The audiograms represented 5,816 different individuals—3,212 factory workers and 2,604 flight line personnel There were 3,229 repeat audiograms The repeat audiograms included both periodic recheck and special medical referrals, and it was not possible from the record to differentiate between these two

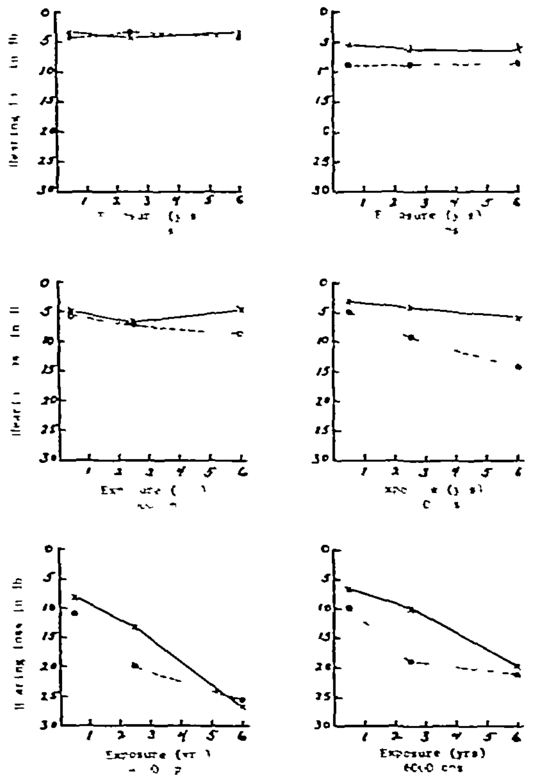
Supplementary information provided with the audiograms included age, history of exposure to noise, job category and medical history Age was indicated by groups of years only, 18-25 years, 26-35 years, 36-45 years and 46 years or over Exposure to factory noise was recorded in three classes less than one year, 1-5 years and 5 years and over Flight line (jet) exposure time was specified in hours 0-100, 100-500, and 500 hours or over Most persons had work experience in more than one job category The largest "pure" work group, 1,196, was made up of riveters Accurate serial records of noise-exposure factors and of information about changes in medical or work history were not always available

The data contained evidence of the production of hearing loss by noise-exposure Fig 1 shows curves of hearing loss vs years of noise-exposure for groups of male factory workers Separate curves are presented for each of three age groups 18-25, 26-35 and 36-45 years Note that the curves show increasing high frequency hearing loss with increasing exposure time At frequencies below 2000 c.p s there is less evidence of systematic change Hearing loss as a function of years of exposure for 1,190 riveters is plotted in Fig 2 According to the information available in the records, these men had been exposed to riveting noise only Note that the hearing losses shown by these men are very similar to the losses displayed in Fig 1, which represents the entire group of factory workers Tests of statistical significance were applied to these data, and the results indicate that hearing losses at frequencies above 3000 c p s are statistically significant At 3000 c p s, losses in the older age group only are statistically significant, and below 3000 c p s the indicated losses are statistically not significant From these results we would infer that on the average, as the years in noise increase so tive importance of different conditions that contribute to the production of hearing loss? To answer these questions we must have measurements of many noise-exposures and serial audiograms of persons exposed to each noise, serial audiograms consist of an original and several well spaced repeat audiograms The audiometric measurements must be accurate, and the information contained in the description of the noise-exposure must be complete and detailed

The ideal approach to the problem of hearing loss in industry would be to carry out controlled experiments in industrial plants For these experiments we would require ideal testing environments and complete freedom for scheduling tests We would test many persons at repeated intervals of various lengths Different groups of these persons would be exposed to noise of different specific characteristics, and there would be no overlapping of the specific exposures Obviously, practical considerations limit the achievement of such ideal experimental conditions in the field It has been possible, through the generous cooperation of certain companies, to do controlled experiments in the field with small numbers of persons, but for some of the statistical analyses we wish to perform we need many thousands of audiograms It is not possible to collect this special data from large groups of persons in the field We are restricted to the information we can obtain from the data records that are made available to us from hearing conservation programs already organized and carried out in industry As a specific illustration of this type of data analysis, let me describe a recent study made at the Research Center of the Subcommittee on Noise in Industry

RECENT STUDY OF INDUSTRIAL HEARING LOSS

The raw data for this study were obtained from records which had been made available by a large aircraft manufacturer These data were entered on punched cards and were then analyzed with respect to three topics *1* Evidence for hearing loss caused by noise-exposure, *2* differences in hearing loss occurring in different plant occupations within the company, and *3* possible sources of error which might invalidate the results of the study



Median hearing loss for 19 workers with riveting experience only with different lengths of exposure [illegible]

Group X——X [illegible] yrs age [illegible]
O O [illegible]

Fig 2

some disconcerting and unexplained discrepancies which appeared when the curves were compared with hearing loss curves from other studies

Specifically, the average hearing losses at the higher frequencies for both groups from the aircraft plant, (riveters and flight line mechanics) are less than hearing losses for *any* occupational group, even for office workers, measured at a State Fair Hearing Survey conducted at Milwaukee, Wisc, in 1954 This result suggests that a search should be made for possible sources of bias in both sets of data Some unspecified selective factors may have operated in the assign-

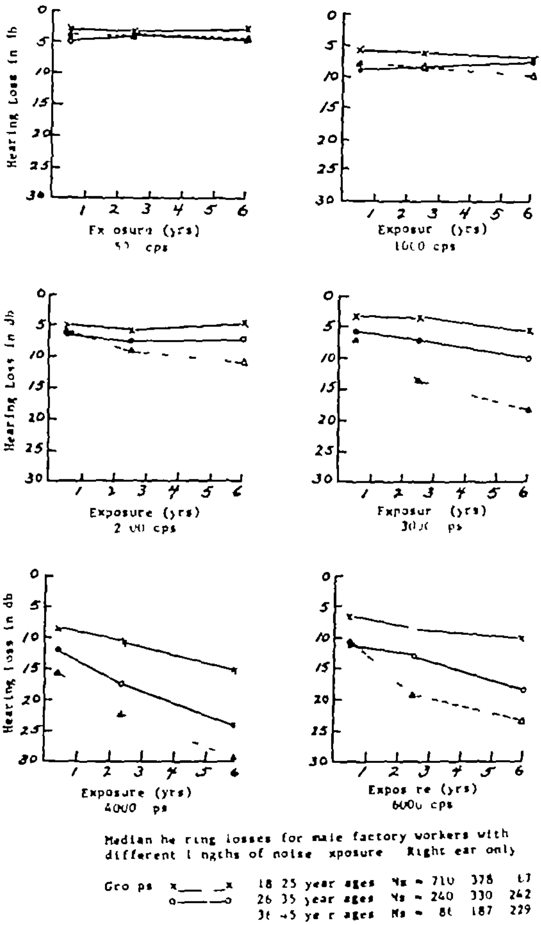
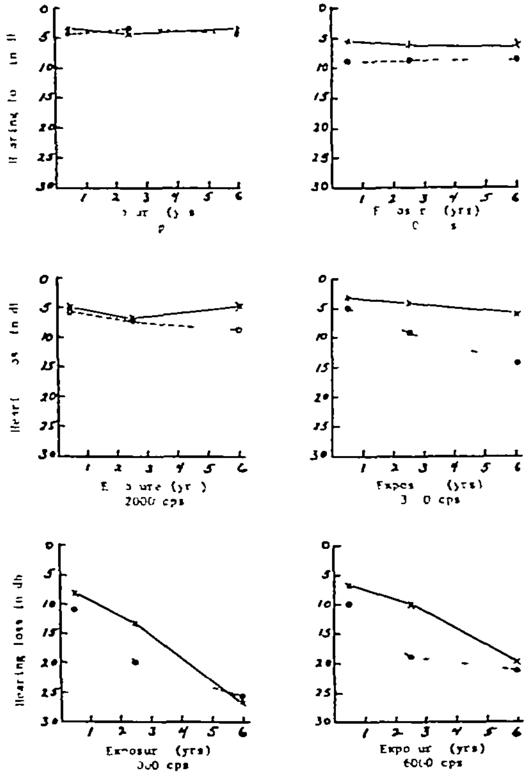


Fig 1

does hearing loss increase at tested frequencies above 3000 c p s

The data were also analyzed with respect to differences in hearing loss that might occur in different occupations in the aircraft company A comparison of the hearing losses of riveters and of jet flight line mechanics may be made from the curves presented in Fig 3 Note that there is a consistent difference between the median losses of the two groups, but that the flight line mechanics have the better hearing in all age groups The differences are probably statistically significant, but tests for statistical significance were not made because of



Median hearing loss for 1190 workers with riveting experience only with different lengths of exposure Right ear only

Groups X——X 18 year age N = 604 161 2
O O 26 3 year ages Ns = 169 143 93

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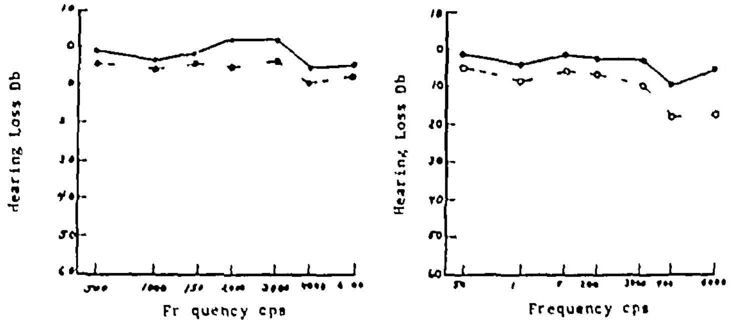
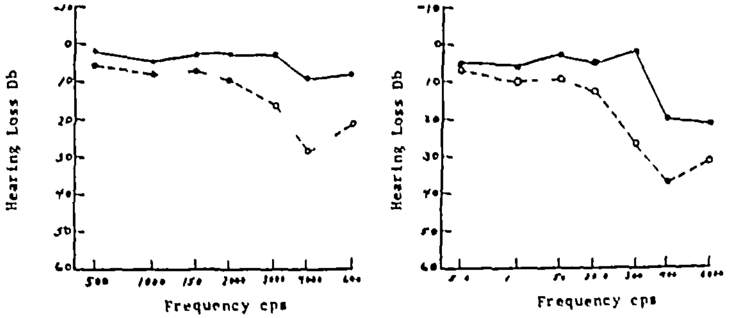


(18 25 Year Age Group)

(26 35 Year Age Group)



(36 45 Year Age Group)

(46 Year and Older Group)

Comparison of median hearing losses for men with riveting experience and with jet engine flight line exposure Right ear only

Groups •——• Jet engine flight line exposure
o —• Riveting

Fig 3

ment of men to a particular work category in the aircraft plant, then too, the audiograms in this plant may have been influenced by certain medical referral policies

The records with the serial audiograms were checked carefully for obvious errors such as decreasing age, impossible changes in years of noise-exposure such as a history of five years in noise on one record and six months later a history of seven years in noise, etc These data showed errors of this type in less than 1 per cent of the records

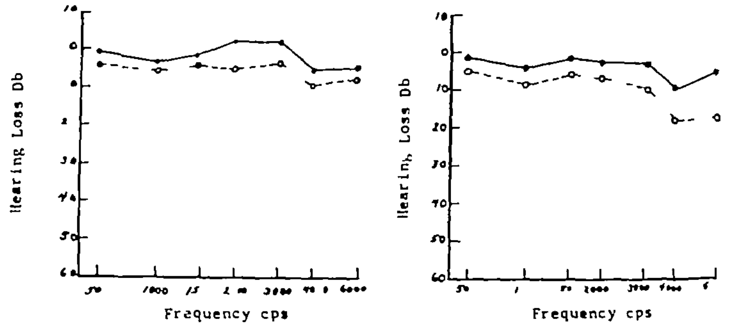
What then have we learned from this analysis? The data indicate that in general, high frequency hearing loss increases with increase in noise-exposure time up to six years, the time period for which data were available, that within the company jet flight line mechanics show less loss than riveters, and that these riveters and mechanics show less hearing loss than do comparable age groups in another study of men in what are considered to be *non-noisy* occupations Findings such as the latter are unexplained at present, and we are understandably reluctant to accept at face value, or to publish without explanation, the results of this and other similar studies

Our experience, as exemplified in the study above, has indicated that many of the differences between groups of data are not strictly related to differences in noise-exposures, or even to such relevant factors as age Before we can draw valid conclusions about the relation of hearing loss to noise-exposure, we must find ways to minimize the importance of, or to control statistically the factors that are not related to the noise-exposure The remainder of this paper will be devoted to a discussion of some of the difficulties encountered in gathering and analyzing data from field studies of noise-induced hearing loss and to a brief description of attempts that are being made to effect the necessary controls

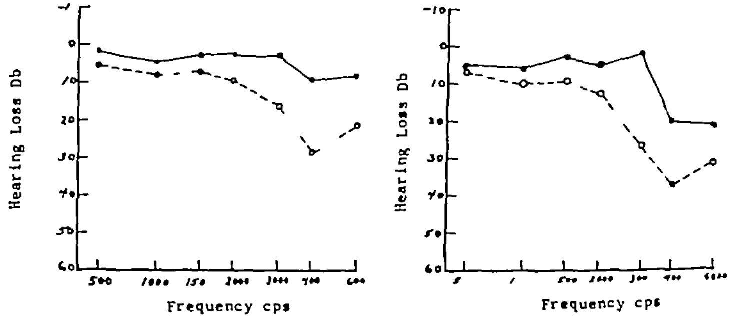
EXPERIMENTAL DIFFICULTIES

In the main, the difficulties encountered in our field research in industry are of two kinds those peculiar to studies of noise-induced hearing loss and those common to all experiments Three of the problems peculiar to studies of noise-induced hearing loss are

1 *Description of Noise-exposure* One of the most difficult problems associated with a study of noise-exposure is that of devising a method of describing and categorizing in a meaningful way the multitudinous types of noise-exposure encountered In order to describe noise-exposure adequately for correlation purposes, some numerical method of classification must be evolved This method of classification must provide a way of combining the measurement of quantity of sound



(18 25 Year Age Group) (26 35 Year Age Group)



(36 45 Year Age Group) (46 Year and Older Group)

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Groups •——• Jet engine flight line exposure
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2. *Temporary Threshold Shift.* A second difficulty peculiar to studies of hearing loss is caused by the temporary hearing loss that results from several hours exposure to noise. Recovery from this loss is usually complete a few hours after cessation of exposure, with the major part of the recovery normally occurring in the first 30 to 60 minutes. The existence of this temporary loss, or *temporary threshold shift,* has an important influence on the validity of field data. Recent measurements made in our laboratory indicate that at 4000 c.p.s. the temporary threshold shift resulting from two hours' exposure to white noise may be less than 5 db. in one person and more than 35 to 40 db. in another. Fig. 4 shows the mean threshold shift of a group of ten subjects whose hearing was measured at half-hour intervals, during and after a two-hour exposure to white noise of 100 db. overall sound pressure level. There appears to be no systematic variation in the size of the shift experienced by different individuals.

We have also made field measurements of the temporary threshold shift caused by exposure to typical industrial noises. These measurements were made throughout the workday on several hundred employees of an aircraft company. The field findings confirmed the laboratory findings.

If industrial hearing tests are made late in the workday after employees have experienced several hours of exposure to noise, the resulting audiograms will be contaminated by temporary threshold shifts. Temporary threshold shift, as a function of the time of day the audiogram is made, can cause a considerable variation in an individual's audiograms, therefore, if some correction for temporary threshold shift is not applied to industrial audiograms the true threshold of hearing will be disguised by temporary threshold shifts, and much of the available field data will not be suitable for studies of permanent hearing loss.

energy with measurements of its time distribution The result might be called a "noise-exposure-index" One approach to the total problem would be to index noise-exposure first with respect to its *physical dimensions*, and then as a further step, to index the effects of the noise-exposure on man The problem of assessing noise-exposure is very complex, and large amounts of data must be gathered and analyzed before we can say what a practical and useful assessment of noise-exposure is

Recent measurements indicate that sufficiently detailed information about the energy content of noise-exposure is not provided by RMS measurements A report from Harold Crouch, of Eastman Kodak Co, shows that although the RMS values of overall levels of certain so-called "steady state" noises were in the region of 100 db, the instantaneous levels were as high as 120 db for 10 per cent or 15 per cent of the time In my opinion, evidence such as this must not be overlooked We may find that peak factors in noise-exposure correlate better with resulting hearing loss than do some of the factors we have already considered, such as the frequency distribution of energy in the noise-exposure In spite of the variability of the industrial processes and of the accompanying noise-exposures, large numbers of industrial audiograms show the same type of hearing loss the loss begins in the region of 4000 c p s and spreads in both directions as exposure time increases It appears then, that energy content of noise, its peaks, its time distribution and its total duration, regardless of spectral distribution, are factors which bear close scrutiny

Although we are cognizant of the fact that time plays a part in the production of hearing loss, we have not yet learned what time interval is most suitable for correlation purposes, should it be one work day, one work year, or some point between?

The Research Center of the Subcommittee on Noise in Industry has recently undertaken a program of gathering and analyzing detailed information about noise-exposures The first goal of this program is to devise a method of indexing noise-exposures from measurements of their physical parameters, the second goal, which I fear will not be realized for some years, will be to index the auditory effects of various noise-exposures on man

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In what ways can we control the effect of temporary threshold shift? Ideally, we might use only those audiograms that were made at least 16 hours after cessation of exposure to noise. This obviously limits us to too few audiograms for good statistical analyses. On the other hand, it is impossible for industry to make all audiograms at the beginning of the workday before employees have been exposed to noise. Our most fruitful approach seems to be to devise some valid statistical method for controlling the effect of temporary threshold shift. We hope to gain enough information from our laboratory studies and from analyses of large numbers of industrial records which include the time of day the audiogram was made to be able to devise such a method. The laboratory measurements will tell us, for continuous exposure to noises which are similar to white noise, how much temporary threshold shift is to be expected on the average at different hours during the work day. Incidentally, it should

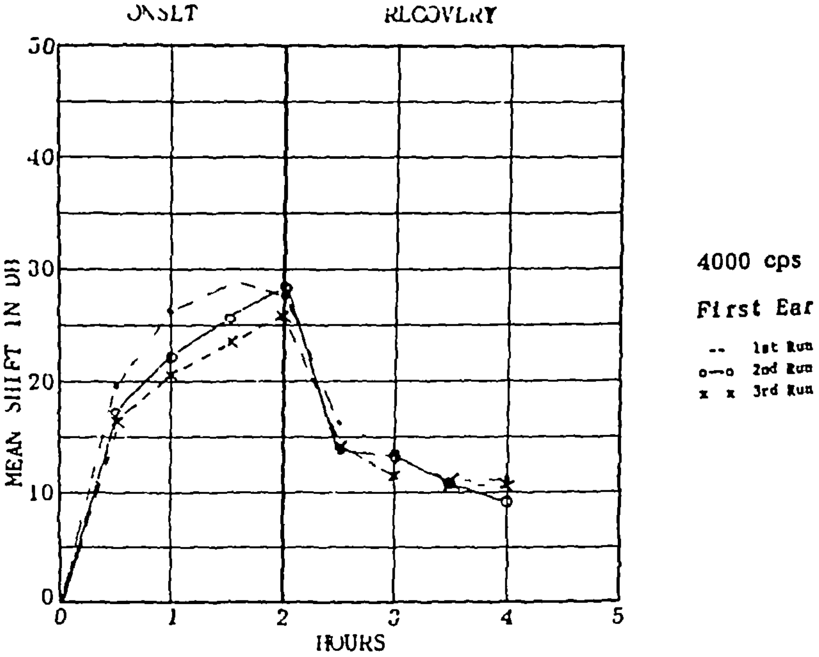

Fig 4

be made clear that recording the time of day the audiogram was made is not sufficient, a statement which describes the amount of noise-exposure prior to the time of giving the hearing test should also be included Further, there are promising indications from our studies of industrial records that if we have a measure of the noise-exposure we may be able to use late-in-the-day audiograms to predict the average "pre-exposure" threshold for a group of employees, or as I prefer to call it, the average *resting* threshold for the group

3 *Hearing loss that accompanies age* A third difficulty which besets the study of noise-induced hearing loss is the compounding of inner-ear hearing losses due to several causes Age, otological disease and noise-exposure may all produce inner-ear hearing loss There is no way of telling from the individual audiogram which of these causes produced a given loss Assuming that we can identify all cases of otological disease from medical histories and so can eliminate them from samples to be studied, we are still faced with the problem of separating noise-induced hearing loss from "age-induced" hearing loss

There is a semantic difficulty here as well as a procedural problem Let me explain The word most commonly used to denote loss of hearing with age in "presbycusis " Strictly speaking, "presbycusis" denotes only that there is a relation between hearing loss and age, it does not specify what the relation is The meaning of the word has become somewhat restricted, however, by usage and by analogy with the restricted meaning of other terms containing the prefix "presby- " In medical literature, the word "presbycusis" has been used commonly to denote hearing loss that accompanies age and that results only from physiological changes that occur with the passage of time Schuknecht* describes the cause of presbycusis as "degenerative changes beginning at the basal end of the cochlea and extending toward the apex, affecting almost equally and simultaneously the various structures within the cochlear duct, including the afferent and efferent nerve fibers The formation of this atrophic lesion resembles the age process known to affect other tissues as age increases"

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*Schuknecht, H. F Prebycusis The Laryngoscope 45 402-419 June 1955

Although the term "presbycusis" is not now so restricted, we feel that it should be reserved to denote specifically the hearing loss that is produced as a result of the aging process, and that is not directly related to environmental factors In addition to the term "prebycusis," then, we need words to describe inner-ear hearing losses caused by noise-exposures The large hearing losses of noise workers certainly cannot be considered as a true reflection of changes produced by age alone, in part, these losses are caused directly by the environment There is also some indication that a large proportion of the population, including persons not employed in noisy occupations, may sustain an average noise-induced hearing loss that is greater than presbycusis but is considerably less than the average noise-induced occupational loss This smaller noise-induced loss results presumably from exposure to social and domestic noises that are common in our society We are now making measurements to determine the magnitude of this loss

At this time we consider inner-ear hearing losses not caused by otological disease to be made up of one or more of these three losses

1 The loss produced by physiological aging processes, or "prebycusis" Presbycusis has no direct causal relation to noise-exposure

2 The loss produced by noise-exposures not greater than those found in ordinary environmental social situations For want of a better term this hearing loss might be called "sociocusis" Sociocusis is causally related to the noise-exposure encountered in non-occupational pursuits and/or in occupations where the noise levels do not ordinarily exceed those found in our social environments The noise-exposures in most offices, for example, are less than the exposures one encounters in many social and domestic activities such as riding in an automobile with the windows open, operating washing machines, vacuum cleaners, electric mixers and other noise producing home appliances These two losses, presbycusis and sociocusis, are not necessarily related to one's occupation Disease, diet, stress and social environmental noise undoubtedly produce a gradual loss of hearing which increases with advancing age This concept of "wear and tear" on the auditory system from non-occupational causes must be considered if we are to come to any sensible decision regarding noise-induced hearing loss

3 The loss produced by industrial or military high level noise-exposures, or, if you will, "occupational hearing loss"

In order to draw conclusions regarding the auditory effects of specific noise-exposures we must provide a method for separating out the non-noise-exposure-related hearing loss Our present concept is that occupational hearing loss and the hearing loss accompanying age are additive losses The true nature of the interrelation of noise-exposure and other causes of hearing loss remains to be determined, but until it is, we shall continue to assume that inner-ear hearing losses, from whatever cause, are additive Under this assumption we determine the average occupational hearing loss as follows *1* measure the total hearing loss, *2* subtract from this measured hearing loss the amount of loss to be expected from non-occupational causes, the remainder is the occupational hearing loss How large is the expected non-occupational loss? The answer may be found by measuring the hearing of many persons who have no otological disease and who have not been exposed to high noise levels for extended periods of time The curves shown in Figs 5 and 6 are representative of the "non-occupational hearing loss that accompanies age" for males and females respectively These curves "summarize" the hearing measurements made on several hundred male office workers and female office workers, housewives, etc, with no history of disease or occupational noise-exposure

FIELD EXPERIMENTS DIFFICULT TO CONTROL

Let us now consider some of the difficulties associated with the actual gathering of data in the field

First, from a practical standpoint the process of hearing measurement alone presents many almost insurmountable nerve fibers The formation of this atrophic lesion resembles the age process known to affect other tissues as age increases"

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CURVES OF PRESBYCUSIS PLUS SOCIOCUSIS (NON-OCCUPATIONAL HEARING LOSS THAT ACCOMPANIES AGE) FEMALES WITH NO HISTORY OF OCCUPATIONAL NOISE-EXPOSURE 1954 WISCONSIN STATE FAIR HEARING SURVEY

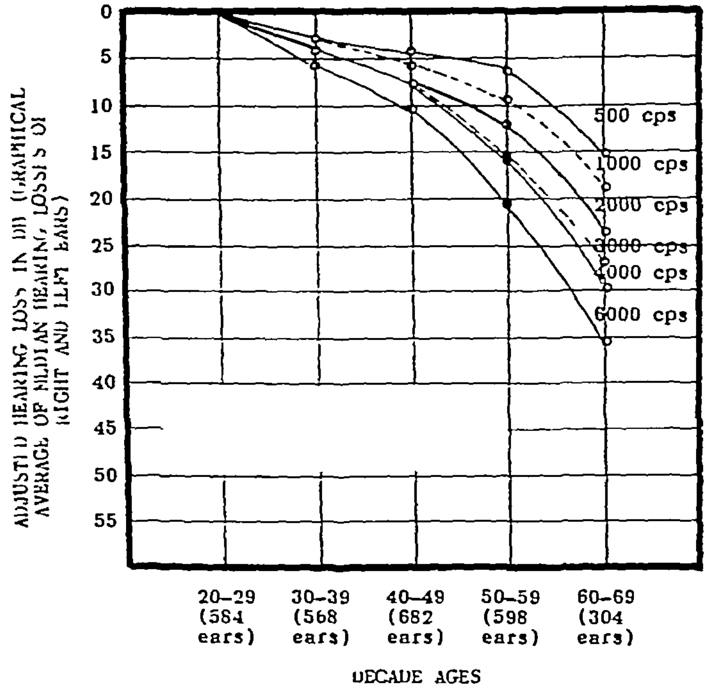


Fig 6

Second, in spite of the availability of prefabricated test booths, the environmental conditions under which most industrial audiometry is done leave much to be desired We are now engaged in an educational campaign to make industrial and military physicians and technicians fully aware of the importance of proper test conditions The pertinent information is made available in the revised Guide, in journal articles, in special training courses offered for audiometric technicians, etc

Third, an examination of the methods of recording data reveals variations, inadequacies and errors which make it almost impossible to use much of the available material difficulties For research purposes we should have measurements of threshold responses to pure tone stimuli, but it is practically impossible to make such measurements for the employees in large industries A trend toward screening audiometry is becoming evident in the larger plants There is usually time for threshold tests during the pre-employment physical examinations, however, and we have consistently urged that threshold hearing tests be made a part of this examination We have also recommended that rapid follow-up tests of hearing or recheck tests be made for many employees with the single frequency screening method devised by Dr Howard House and myself The time saved by use of this screening technique should make it possible for most industries to give threshold tests to employees whose hearing has undergone a significant change These recommendations and many others have been made available to industry in our revised Guide for Conservation of Hearing in Noise, published in 1957

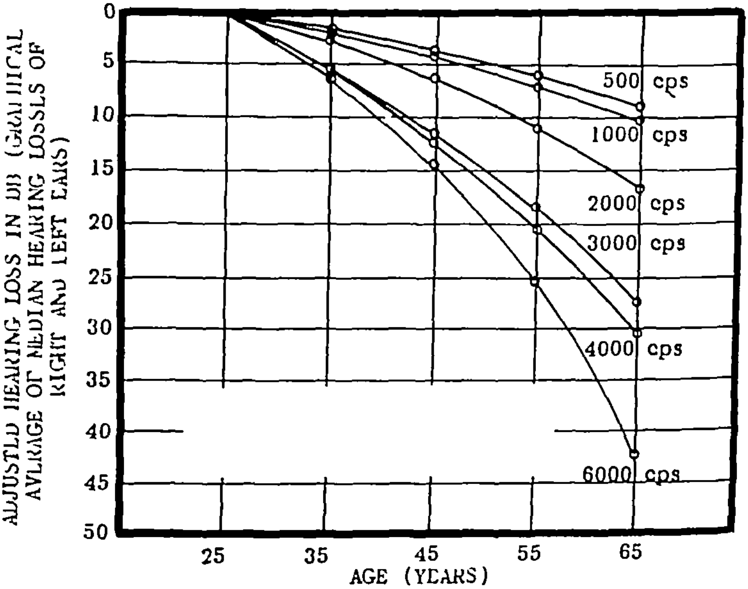


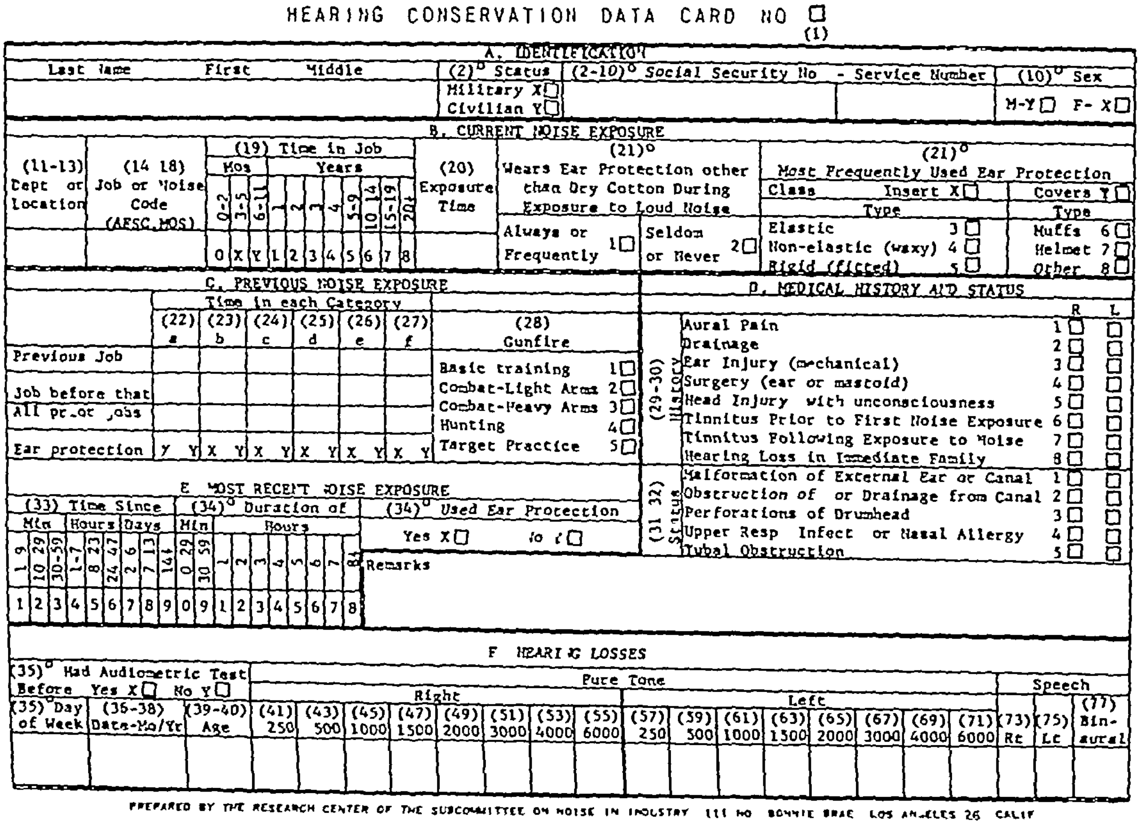
Fig 5 Curves of presbycusis and sociocusis (nonoccupational hearing loss that accompanies age) male office workers—1954 Wisconsin State Fair Hearing Survey (604 ears)

Fourth, one of the worst problems to contend with in the use of industrial data is the rapid turnover of personnel Very few noisy industries employ the same personnel over long enough periods of time for us to make fruitful studies of hearing loss The aircraft companies, for example, have almost a 100 per cent turnover per year in their noisy departments Consequently, it is unusual to be able to follow the same person with repeat tests for more than a few months at a time For this reason, we must obtain very large amounts of data if we are to draw valid conclusions about industrial hearing loss in general

Fifth, audiometric data is subject to the usual errors of sampling and measurement Such errors may make measured values consistently larger than or smaller than the "true" value Variable errors may cause measured values to fluctuate from one occasion to another and thereby "hide" changes or relationships in a maze of variable unstable numbers Company policy for assigning men to various jobs may give rise to sampling bias by producing an occupational group within the company that is not typical of the occupation in industry as a whole Errors may result from failure to control relevant factors while measurements are being made Audiometric measurements, for example, are known to be influenced by such effects as practice and fatigue Experimenters must be careful to equate comparison groups in such matters as age, sex, etc The calibration of the equipment must not be changed between the time of testing one comparison group and another

CONCLUSIONS

In spite of the many very real difficulties that are encountered in field studies of industrial hearing loss we feel that industrial and military audiometric data can be used to good advantage if they are properly recorded and if the necessary supplementary information is included in each record For research purposes, industrial records should contain *at least,* *1* the age, in years, of the person tested, *2* a standardized specification of the noise environment, *3* an accurate record of the man's exposure history, *4* a statement of the reason



HEARING CONSERVATION DATA CARD NO ☐ (1)

A. IDENTIFICATION

Last Name First Middle

(2)° Status: Military X☐ Civilian Y☐

(2-10)° Social Security No - Service Number

(10)° Sex: M-Y☐ F- X☐

B. CURRENT NOISE EXPOSURE

(11-13) Dept or Location

(14 18) Job or Noise Code (AFSC, MOS)

(19) Time in Job

Mos			Years							
0-2	3-5	6-11	1	2	3	4	5-9	10-14	15-19	20+
0	X	Y	1	2	3	4	5	6	7	8

(20) Exposure Time

(21)° Wears Ear Protection other than Dry Cotton During Exposure to Loud Noise: Always or Frequently 1☐ Seldom or Never 2☐

(21)° Most Frequently Used Ear Protection

Class: Insert X☐ Covers Y☐

Type: Elastic 3☐ Non-elastic (waxy) 4☐ Rigid (fitted) 5☐

Type: Muffs 6☐ Helmet 7☐ Other 8☐

C. PREVIOUS NOISE EXPOSURE

Time in each Category

	(22) a	(23) b	(24) c	(25) d	(26) e	(27) f
Previous Job						
Job before that						
All prior jobs						
Ear protection	Y Y	X Y	X Y	X Y	X Y	X Y

(28) Gunfire

Basic training 1☐
Combat-Light Arms 2☐
Combat-Heavy Arms 3☐
Hunting 4☐
Target Practice 5☐

D. MEDICAL HISTORY AND STATUS

		R	L
(29-30) History	Aural Pain	1☐	☐
	Drainage	2☐	☐
	Ear Injury (mechanical)	3☐	☐
	Surgery (ear or mastoid)	4☐	☐
	Head Injury with unconsciousness	5☐	☐
	Tinnitus Prior to First Noise Exposure	6☐	☐
	Tinnitus Following Exposure to Noise	7☐	☐
	Hearing Loss in Immediate Family	8☐	☐
(31 32) Status	Malformation of External Ear or Canal	1☐	☐
	Obstruction of or Drainage from Canal	2☐	☐
	Perforations of Drumhead	3☐	☐
	Upper Resp Infect or Nasal Allergy	4☐	☐
	Tubal Obstruction	5☐	☐

E. MOST RECENT NOISE EXPOSURE

(33) Time Since

Min	Min	Min	Hours	Hours	Days	Days	Days	Days
1-9	10-29	30-59	1-7	8-23	24-47	2-6	7-13	14+
1	2	3	4	5	6	7	8	9

(34)° Duration of

Min	Min	Hours							
0-29	30-59	1	2	3	4	5	6	7	8+
0	9	1	2	3	4	5	6	7	8

(34)° Used Ear Protection: Yes X☐ No Y☐

Remarks

F HEARING LOSSES

(35)° Had Audiometric Test Before Yes X☐ No Y☐

			Pure Tone																Speech		
			Right								Left										
(35)° Day of Week	(36-38) Date-Mo/Yr	(39-40) Age	(41) 250	(43) 500	(45) 1000	(47) 1500	(49) 2000	(51) 3000	(53) 4000	(55) 6000	(57) 250	(59) 500	(61) 1000	(63) 1500	(65) 2000	(67) 3000	(69) 4000	(71) 6000	(73) Rt	(75) Lt	(77) Bin-aural

PREPARED BY THE RESEARCH CENTER OF THE SUBCOMMITTEE ON NOISE IN INDUSTRY 111 NO BONNIE BRAE LOS ANGELES 26 CALIF

Fig 7

Recognizing the importance of accurate records, we devised a standard form for recording hearing conservation data This form, called a "Hearing Conservation Data Card" is shown in Fig 7 The Data Card is unquestionably a step in the right direction, but undoubtedly it will be years before it will be accepted by industry in general and limitations, future industrial data can be used to good advantage if certain remediable faults are corrected

A LABORATORY METHOD FOR THE STUDY OF ACOUSTIC TRAUMA [*]

DONALD H ELDREDGE,
and
WALTER P COVELL,

Central Institute for the Deaf and Washington University,

St Louis, Mo

To begin I should like to stress two points first, the work to be discussed here is part of a continuing project to learn more about acoustic injury of the ear Many others working at the Central Institute for the Deaf, especially Drs Davis, Riesco-MacClure, Fernández, Tasaki, Legouix, Goldstein and Benson, have made major contributions to these techniques in the past Dr Davis continues as our most helpful advisor, and, when he has time left over from his many other duties and researches, is still an active collaborator

Second, we are really studying acoustic trauma in the laboratory, and this is quite different from the subject matter of the other presentations of this morning Ideally, in planning this program Drs Silverman and Hirsh would like to have had someone describe the pathologic physiology of human ears which had been exposed to the noise of, say a drop forge for 5, 10, 20 and 30 years This is not possible, and so we are to discuss acoustic injuries to the guinea pig ear We would like to know about real deficits in hearing function, but we must look at cochlear potentials and cochlear anatomy in the guinea pig We would like to know about exposures that continue for years, instead, our experimental exposures last minutes to hours Although some results from our experiments will be presented, the title, "A Laboratory Method for

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[*] Supported by Contract No AF 33(616)-3637 between Washington University and the Bio-Acoustic Branch of the Aero Medical Laboratory Wright Air Development Center

Reproduction in whole or in part is permitted for any purpose of the United States Government for making the audiogram, and 5 the date and time within the work cycle when the measurement was made

SUMMARY

Finally, let me summarize the main points of the paper 1 Design in industrial field research is largely restricted to appropriate tailoring of existing data production methods It is unlike laboratory research where experiments can be designed to yield the type of data needed, and since manipulative controls are not feasible, statistical controls must be provided during analysis of the data—a situation which generally requires the collection of very large amounts of data 2 Many restrictions are imposed on the use of audiometric data obtained through usual industrial channels, because most industrial groups are not homogeneous as to noise-exposure history, job continuity, use of ear protection, and time of hearing test during a day Further, because companies differ in their method of record keeping, the data are likely to vary in respects that may limit the usefulness of the information in studies which combine company samples Although such restrictions do not make the data useless they do point out the need for careful scrutiny and skillful analysis if valid conclusions are to be drawn 3 There are a large number of specific factors which can reduce the validity of data collected in industrial situations Some of these factors can be eliminated For example, poor testing environments poorly trained audiometric technicians, obvious errors in data recording, and nonstandard or inadequate methods of data recording On the other hand, there are many conditions which cannot be altered For example, it is improbable that industry in general will be able to make all audiograms after a period of absence from noise-exposure 4 Data will be more useful if the forms used to record the data are standardized In a standard form particular attention should be paid to details of noise-exposure, to time of hearing tests, and to the reason for the hearing tests 5 Explanations for some of the discrepancies disclosed in industrial data are (a) biases operating in the selection of the sample and (b) nonrepresentativeness of the audiograms 6 In spite of restrictions the values for “threshold” shift corresponding to these injuries is slightly less, the general trend is the same

The preparation of good temporal bone specimens for microscopic study is a slow tedious process, and the “feedback” of information from one experiment to the next is very slow if we rely solely on this method, however, one knows the “threshold” shift for the CM immediately, and using the information from this slide, can quickly estimate the anatomical degree of an acoustic injury In addition, other electrophysiological potentials can be measured When these are compared to each other and to the anatomical injuries later observed, there is a good possibility that our understanding of the pathologic physiology of acoustic trauma will be improved These ideas were basic to our plans for the experiments I will describe

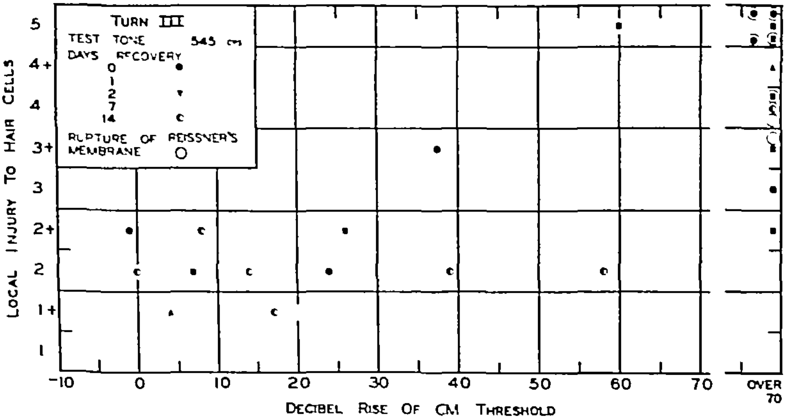


Fig 2 Local injury to the hair cells in the third turn plotted against decibels rise of CM threshold for 500 c.p s in the third turn The symbols correspond to the different durations of the recovery period.

Now let us ask a question about acoustic trauma What reciprocal changes in the intensity and duration of an acoustic stimulus will produce a constant injury to the organ of Corti? For years we have been aware that brief, but intense, stimuli (for example, an explosion) can leave a permanent hearing loss Other stimuli which are apparently harmless for short the Study of Acoustic Trauma," was chosen to emphasize that we are not talking about Hearing Loss and Noise Exposure in the main sense of this session

Some time ago Hallowell Davis[1] and the numerous collaborators mentioned earlier noted a relation between the "threshold" shift for the cochlear microphonic as recorded by differential electrodes placed in scala vestibuli and scala tympani, and the anatomical injury observed between these electrodes after acoustic trauma This relation is shown in Fig 1 The ordinant is an anatomical injury rating scale of nine points Injury ratings of 3, 3+, 4, and 4+ were considered to represent probably permanent injury to the hair cells of the organ of Corti, and were associated with "threshold" shifts of the cochlear microphonic potential of about 40-60 decibels Fig 2, taken from one of our more recent papers,[2] shows the same relation measured after the ears had been allowed to recover from the acoustic trauma for periods up to 14 days Although

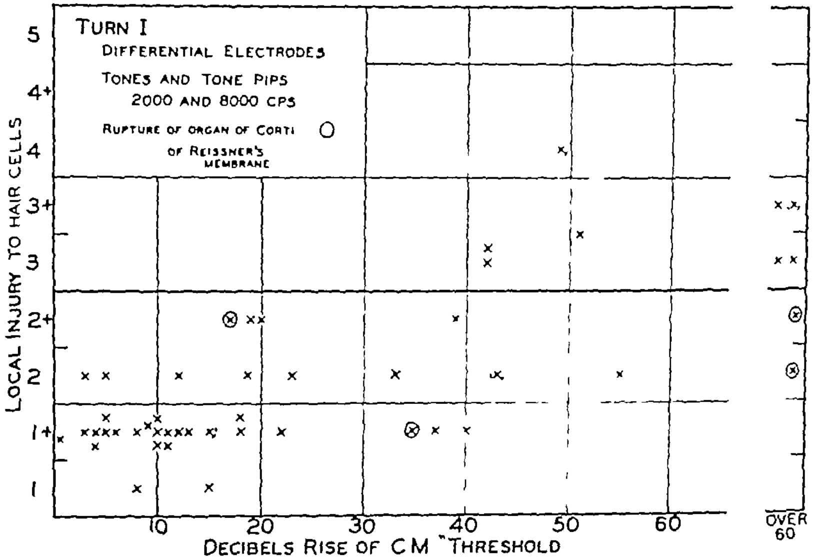


Fig 1 The elevation of the threshold' of the cochlear microphonic as measured in Turn I by differential electrodes The ordinant is an anatomical injury rating scale of nine points The heavy horizontal line divides the probably permanent injuries to hair cells (above) from the probably reversible injuries (below) The crosses represent differential electrodes

ant, and the duration plotted logarithmically in minutes on the abscissa The number of ears in each group varied from one to ten Five to ten ears were used for exposures which gave 40 to 60 db "threshold" shifts, whereas only one, two or three were used to explore the exposures above and below this range Open circles designate average shifts of less

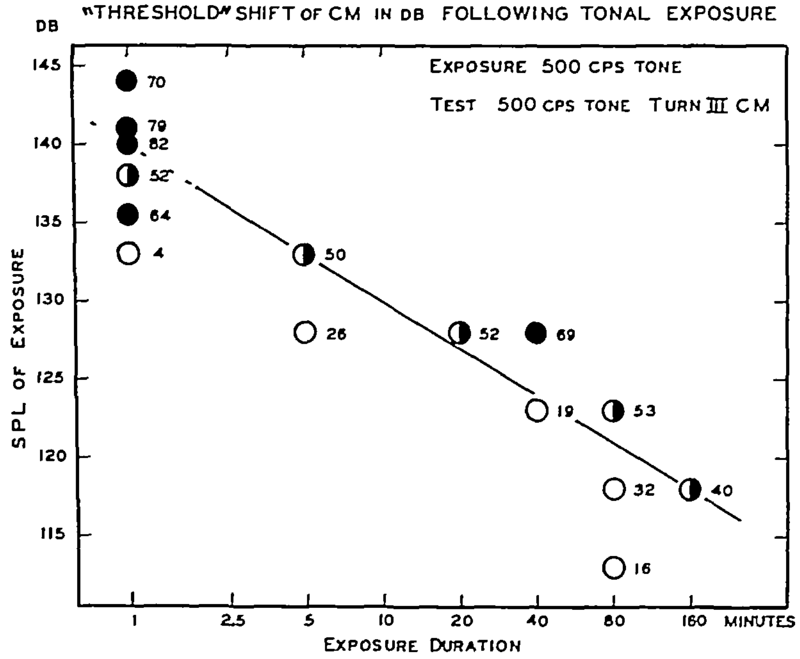


Fig 3 Sound pressure levels and durations of exposures to 500 c.p s tone Numbers indicate average threshold shift for CM from Turn III in response to 500 c.p s test tone Open circles indicate exposures which produced less than 40 db shift half-filled circles indicate 40 to 60 db shift and solid circles indicate more than 60 db shift Line described in text.

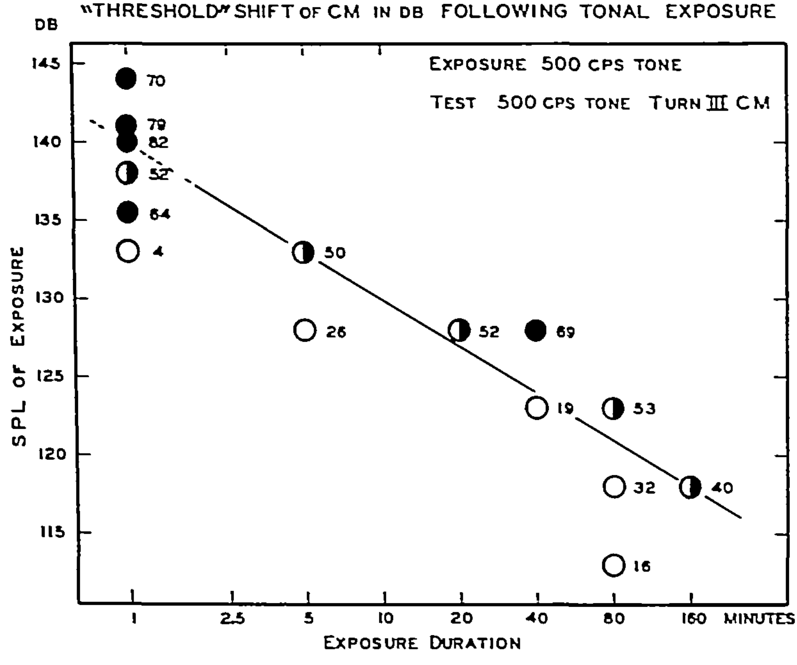
than 40 db, and filled circles represent average shifts of more than 60 db The half-filled circles designate the exposures which produced our criterion shift of 40 to 60 db

For a moment let us turn to the problem of chronic noise-induced hearing loss In trying to arrive at some reasonable way to relate the contributions of sound pressure level and duration of exposures to the hazard of noise exposure, an exposures can produce permanent hearing losses if the exposure is made sufficiently long There is a tremendous continuum between these durations, measured in milliseconds on the one hand and years on the other The first experiment to be described deals with durations of stimuli only between one and 160 minutes We consider these durations to fall in the category of acute acoustic trauma, not chronic noise-induced hearing loss

For the traumatic stimulus we used a 500 c p s tone generated by an enclosed acoustic system sealed to the ear canal of the guinea pig This acoustic system was very stable, and carefully calibrated so that we could specify the sound pressure level of the stimuli at the tympanic membrane within ±2 db Remembering yesterday's presentations, a 500 c p s tone will stimulate all the turns of the cochlea nearly to the apex The greatest amplitude of motion in the basilar membrane will appear in the third turn We would expect the more severe injuries here also, with lesser or possibly no injuries elsewhere along the basilar membrane

Pairs of differential electrodes recording from the first and the third turns were used to measure the cochlear microphonics generated at these two locations The "threshold" shift for the cochlear microphonic produced by a 500 c p s test tone, and measured from the third turn, should indicate the more severe injury The same measure, "threshold" shift for the CM produced by test tones (we used 500, 2000 and 8000 c p s) recorded from the first turn should indicate the degree of anatomical injury in the first turn To avoid the effects of transitory fatigue, the measurements were made one hour after the end of the traumatic stimulus

Taking some clues about critical exposures from previous experiments, we set about exposing guinea pig ears to the 500 c p s tone, planning the experiments as we went along The idea was to use exposures which would "bracket" our criterion injury as indicated by "threshold" shifts, measured in the third turn for a 500 c p s test tone In Fig 3 are shown the exposures used and the average "threshold" shifts for the various exposure conditions Each point represents one group of exposures to the sound pressure level shown on the ordinant, and the duration plotted logarithmically in minutes on the abscissa The number of ears in each group varied from one to ten Five to ten ears were used for exposures which gave 40 to 60 db "threshold" shifts, whereas only one, two or three were used to explore the exposures above and below this range Open circles designate average shifts of less



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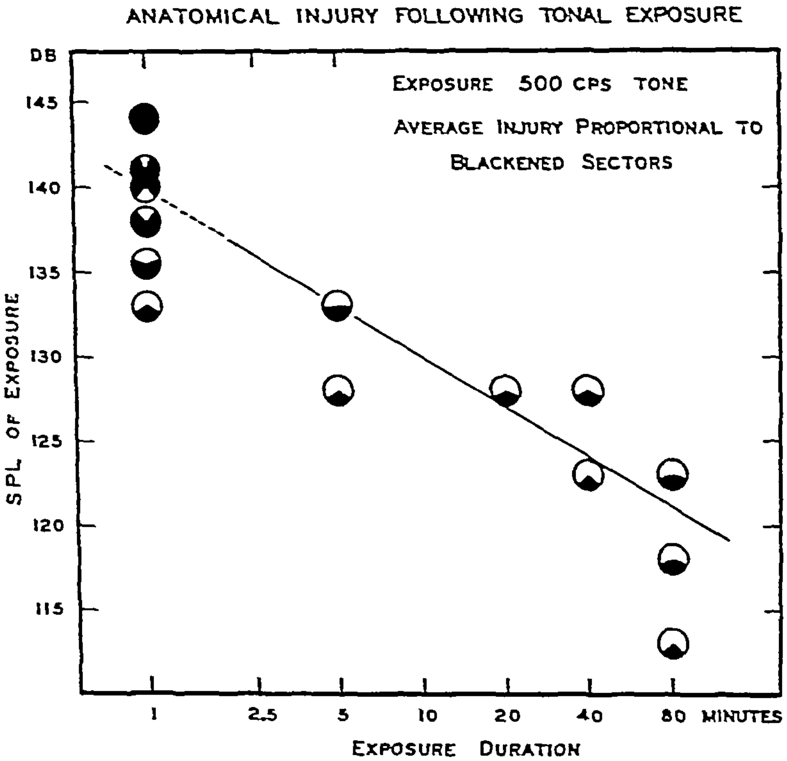

Fig 4 Sound pressure levels and duration of exposures to 500 c.p s tone as in Fig 3. Injury of hair cells in Turn III proportional to amount of blackening of circles

that the sound pressure level decreased only one decibel each time the duration of exposure is doubled, however, we must do the experiments which would "bracket" this new parameter before the parameter can be drawn with any degree of assurance In particular, we must learn the sound pressure thresholds for severe injuries at the longer durations of exposure.

The best we can do so far is to alter our concept of the relation between anatomical injury and "threshold" shift for the cochlear microphonic responses Both can be produced by acoustic trauma, but each relates differently to the exposure dimensions of pressure and duration There is the further condition that definite injury to the organ of Corti equal-energy hypothesis has been proposed by Eldred, Gannon and von Gierke[3] Although there are no direct data to support this hypothesis, the relations so described do not conflict with common experience, and do appear to be more reasonable than other arbitrary assumptions one could make The hypothesis assumes that noise exposures may be equated with respect to hazard when the total acoustic energies of the exposures are equal A set of such equal exposures can be described on a double logarithmic plot of sound pressure and duration by a straight line with a slope such that it goes down 3 db in sound pressure level each time the duration of exposure is doubled

A line which drops 3 db for each doubling of duration has been drawn through the exposure point described by 133 db for five minutes and which gave an average "threshold" shift of 50 db This line rather well describes the parameter of our 40 to 60 db "threshold" shift criterion It does not do so well for the one-minute exposures, and we have reason to suspect that the function described by this parameter is reaching a limit at these sound pressure levels There must also be a similar lower limit, but this has not been sought systematically Parenthetically, I should note that this line should not be confused with other equal-energy parameters which have been proposed as safe for human ears

Before becoming too entranced with the possibilities for speculation on the good agreement between these data and the equal energy hypothesis, we ought to review the pathology produced in these ears The anatomical injuries to the hair cells of the organ of Corti in the third turn were rated on the same nine-point scale which was the abscissa of the first slides In Fig 4 the average injury ratings are depicted by the blackened sectors of the circles These circles are, of course, located in the same exposure position as on Fig 3, and the same equal-energy line has also been carried forward to provide a common reference It is clear that the degree of injury was primarily proportional to sound pressure level, although longer durations of exposure did slightly increase the injury ratings The injury ratings of some of the peripheral points invite a new line, which might have a slope such equal-energy hypothesis has been proposed by Eldred, Gannon and von Gierke.[3] Although there are no direct data to support this hypothesis, the relations so described do not conflict with common experience, and do appear to be more reasonable than other arbitrary assumptions one could make. The hypothesis assumes that noise exposures may be equated with respect to hazard when the total acoustic energies of the exposures are equal. A set of such equal exposures can be described on a double logarithmic plot of sound pressure and duration by a straight line with a slope such that it goes down 3 db. in sound pressure level each time the duration of exposure is doubled.

A line which drops 3 db. for each doubling of duration has been drawn through the exposure point described by 133 db. for five minutes and which gave an average "threshold" shift of 50 db. This line rather well describes the parameter of our 40 to 60 db. "threshold" shift criterion. It does not do so well for the one-minute exposures, and we have reason to suspect that the function described by this parameter is reaching a limit at these sound pressure levels. There must also be a similar lower limit, but this has not been sought systematically. Parenthetically, I should note that this line should not be confused with other equal-energy parameters which have been proposed as safe for human ears.

Before becoming too entranced with the possibilities for speculation on the good agreement between these data and the equal energy hypothesis, we ought to review the pathology produced in these ears. The anatomical injuries to the hair cells of the organ of Corti in the third turn were rated on the same nine-point scale which was the abscissa of the first slides. In Fig. 4 the average injury ratings are depicted by the blackened sectors of the circles. These circles are, of course, located in the same exposure position as on Fig. 3, and the same equal-energy line has also been carried forward to provide a common reference. It is clear that the degree of injury was primarily proportional to sound pressure level, although longer durations of exposure did slightly increase the injury ratings. The injury ratings of some of the peripheral points invite a new line, which might have a slope such or near-normal cochlear microphonics in the senile guinea pig.[4] Other detailed changes in the supporting cells of the organ of Corti are similar to changes observed by Lindsay, Perlman, Fernández and Hemenway[5] following occlusion of the cochlear blood vessels.

It is quite possible that our original injury rating scale is appropriate only to injuries produced by stimuli which produce motions that exceed certain elastic limits. We may need to develop a new scale for rating the injuries produced by the lower sound pressure and longer duration exposures.

Another question we have asked is "how do pure tones compare with noises in their ability to injure the organ of Corti?" The critical band hypothesis, which has been found extremely useful in psychophysical experiments, suggests one possible relation. Given a flat spectrum noise which just masks a pure tone, only a narrow band of frequencies around the pure tone actively contributes to the masking. This critical band of frequencies has the same acoustic energy as the pure tone. The overall pattern of stimulation on the basilar membrane for the tone and for the critical band can be inferred to be the same or very nearly so, and to be equally broad. If injury to the organ of Corti depends upon the energy actually delivered to a particular region of the basilar membrane we would expect a pure tone and its critical band to be equally injurious.

A 300-600 c.p.s. band of noise contains more frequencies than the critical band for 500 c.p.s., and presumably distributes energy to a larger portion of the basilar membrane than does a 500 c.p.s. tone. If the total energy delivered to the basilar membrane is the same for the 300-600 c.p.s. band of noise and for the 500 c.p.s. tone, the area of the basilar membrane giving the greatest response to 500 c.p.s. tones will have a higher energy density when the stimulus is the tone, than it will have when the stimulus is the band of noise. Data supporting the critical band hypothesis in man tell us that the energy concentration in this area should be about 7 db. more for the pure tone. If the injury at this location on the basilar membrane depends upon the energy density, it should be necessary for the overall rms level of the 300-600 nearly always produces a deficit in the cochlear microphonics as we measure them, whereas a deficit in the cochlear microphonic response is not always accompanied by the definite injuries we are accustomed to recognize as such

In Fig 5 is shown one injury that is more difficult to interpret in terms of probable function than others we have seen more often in the past The hair cells of the organ of Corti do not appear badly injured, but the Deiters cells supporting them have been injured to the extent that portions of these cells are torn off and deposited in the tunnel of Corti From other studies[2] we infer that these hair cells should regain a normal appearance, but we do not know whether they will be properly attached to the basilar membrane by the Deiters cells so that they can function normally Similarly we are not sure of the functional significance of loss of mesothelial cells Absence of mesothelial cells does not preclude normal

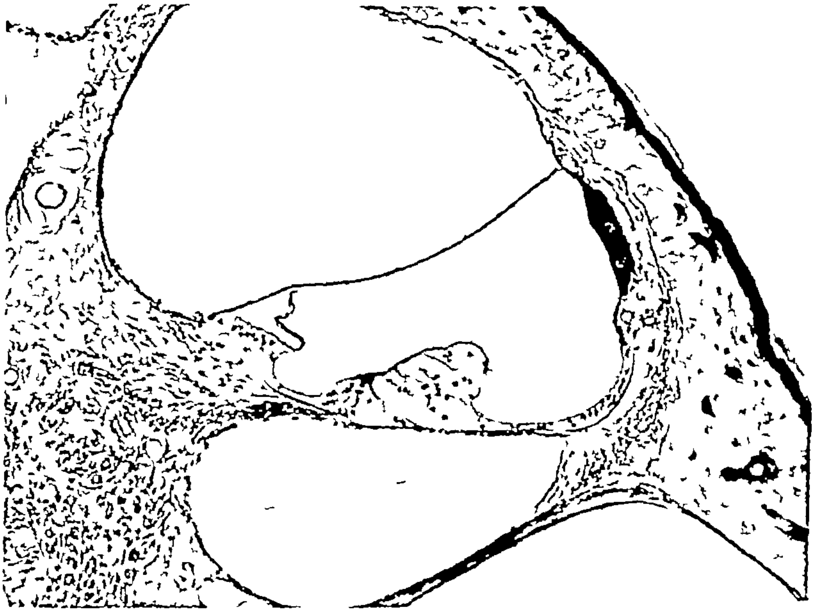

Fig 5 Photomicrograph of a section through the third turn of a guinea pig cochlea showing reasonably intact organ of Corti except for Deiters cells Some are detached from the basilar membrane and globules of their protoplasm appear in the tunnel of Corti—115X.

exposure condition which produced a 40 to 60 db "threshold" shift for the CM from the third turn is six db below the corresponding sound pressure level for the pure tone For this exposure condition we must clearly accept the hypothesis that the peak displacements are primarily responsible for the "threshold" shifts observed At the lower levels and longer durations there is a tendency for the exposure conditions yielding the criterion "threshold" shifts to approach this parameter for the pure tone exposures The data are not sufficient to determine really precise locations or limits for either set of experiments Rather than drawing a second line for the band of noise experiments, we prefer to state that it is different from that for the pure tone and starts at lower sound pressure levels Already we are stretching the time limits for acute experiments of this kind Both the tone and the band of noise parameters could be approaching the same

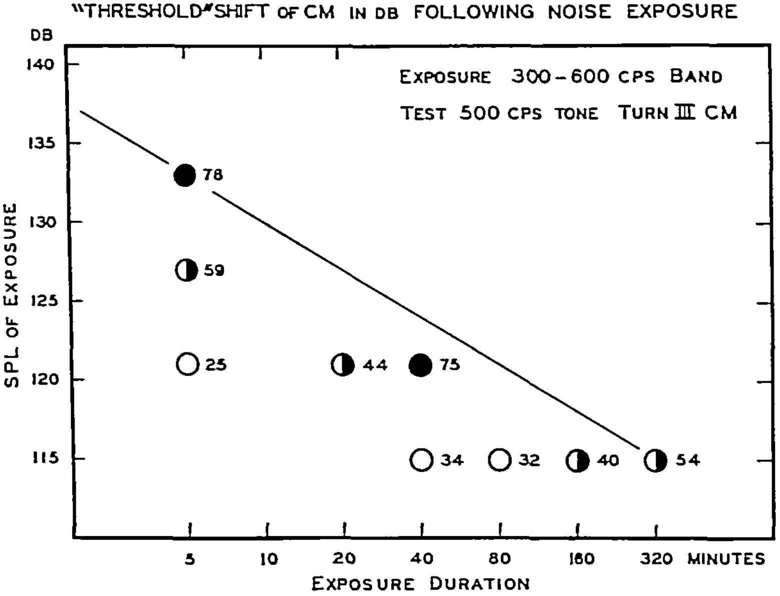

Fig 6 Sound pressure levels and duration of exposures to 300-600 c.p s band of noise Numbers indicate average threshold shift for CM from Turn III in response to 500 c p s test tone Open circles indicate exposures which produced less than 40 db shift and solid circles indicate more than 60 db shift. Line is from Fig 3 for comparison

c p s band of noise to be seven db more than the rms level of the pure tone The noise should then injure a *longer* segment of the basilar membrane, but the most severe local injuries should be the same We do not know the width of a critical band for the guinea pig It should not, however, be different in kind if the critical band hypothesis depends on the space-time pattern of the waves in the basilar membrane, as is assumed for the purposes of this experiment

It is also possible that peak displacements of the basilar membrane, rather than average energy level, are primarily responsible for the injuries we observe This hypothesis depends on the concept of exceeding some elastic limit in the tissues The peak displacements produced by a pure tone are, of course, uniform with respect to time A band of noise of the same overall level will produce displacements of random amplitude both greater and less than that of the pure tone Considerably greater displacements will occur occasionally and could produce more severe injuries We have not tried to quantify the differences, because we do not know the elastic limits of these tissues, however, if injury does depend on peak displacement, the overall sound pressure level of a band of noise required to produce a given injury will be less than that of the pure tone

It is, of course, also possible that the injury may in some way depend primarily on the total energy delivered to the cochlea In this case the injuries should be the same when the overall rms levels of the band of noise and the pure tone are the same

Again using the 40 to 60 db "threshold" shift of the CM, recorded from the third turn, to a 500 c p s test tone as our criterion, we have exposed guinea pig ears to a carefully calibrated 300-600 c p s band of noise The results are shown in Fig 6 The coordinants and the symbols are the same as for Fig 3, showing the "threshold" shifts produced by the pure tones The line which corresponded to the 40 to 60 db "threshold" shift parameter for the pure tone exposures also appears for comparison

For the five-minute exposure the sound pressure level of an exposure condition which produced a 40 to 60 db "threshold" shift for the CM from the third turn is six db below the corresponding sound pressure level for the pure tone For this exposure condition we must clearly accept the hypothesis that the peak displacements are primarily responsible for the "threshold" shifts observed At the lower levels and longer

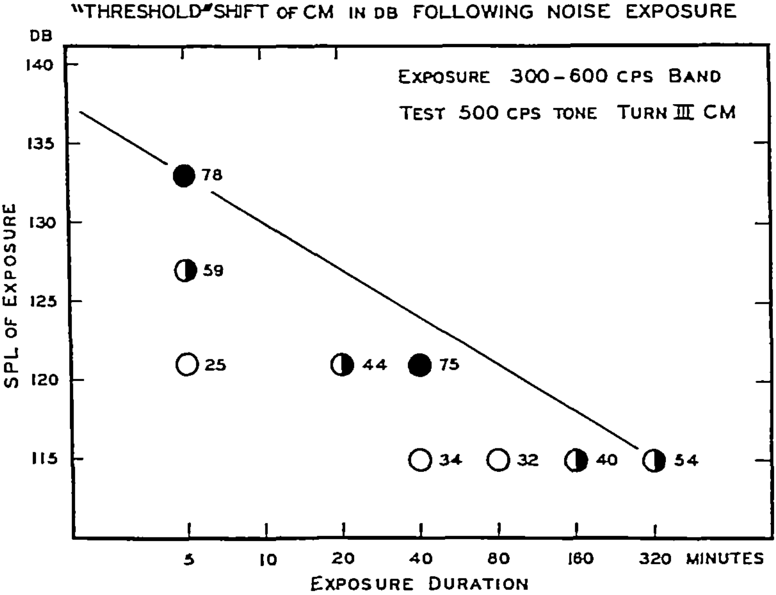

Fig 6 Sound pressure levels and duration of exposures to 300-600 c.p s band of noise. Numbers indicate average threshold shift for CM from Turn III in response to 500 c p s test tone Open circles indicate exposures which produced less than 40 db shift and solid circles indicate more than 60 db shift. Line is from Fig 3 for comparison

durations there is a tendency for the exposure conditions yielding the criterion "threshold" shifts to approach this parameter for the pure tone exposures The data are not sufficient to determine really precise locations or limits for either set of experiments Rather than drawing a second line for the band of noise experiments, we prefer to state that it is different from that for the pure tone and starts at lower sound pressure levels Already we are stretching the time limits for acute experiments of this kind Both the tone and the band of noise parameters could be approaching the same limiting lower sound pressure level, or it is quite possibl that the lines may cross, and at even lower levels and longe durations of exposure they may assume the relation predicte by the critical band hypothesis. Chronic experiments will b necessary before these questions can be resolved.

The temporal bone specimens injured by the band of nois are quite comparable to those injured by the pure tones with respect to the amount of injury to hair cells. As for the exposures to the 500 c.p.s. tone, the shorter, higher-level exposures injured the hair cells more severely than the longer, lower-level exposures. Both stimuli produced maximum degree of injury in the third turn of the cochlea. The areas of injury differed in that the injuries produced by the tone often spread to the upper part of the second turn, while the injuries produced by the band of noise spread toward the fourth turn and often to the apex. It is our impression that there may be other differences. The displacements of cells within the organ of Corti appear relatively greater and more obvious following the noise exposures, and gross rupture of the organ of Corti and of the reticular lamina are less frequent. These displacements are often accompanied by deformation of the tunnel of Corti and by a more frequent swelling of Deiters cells, which then appear to encroach upon and deform the hair cells. The internal phalangeal cell may be tremendously enlarged and the internal hair cell actually displaced. Stretching and rupture of Reissner's membrane occurs more frequently following the longer exposures to the band of noise. For the longest exposures, injury to Reissner's membrane was apparent even when injuries to the hair cells were minor and loss of CM responses only 20 to 30 db. The exposure to the tone (500 c.p.s.), on the other hand, usually appeared to injure more directly the hair cells and the mesothelial cells.

The pathological differences noted are only trends, and may not prove to be significant. Thus we believe the inferences we have drawn from the data on "threshold" shift of the CM responses are correct with respect to the relative hazards of pure tones and bands of noise for the brief intense exposures we have used.

In summary, the "threshold" shift for the cochlear microphonic produced by acute acoustic trauma by a 500 c p s tone obeys the equal-energy hypothesis when the duration of exposure is between five and 160 minutes A 300-600 c p s band of noise at a lower overall sound pressure level than the 500 c p s tone produces the same threshold shift of the cochlear microphonic as the tone From this we conclude that the shifts are related to peak pressures of the stimuli rather than to the energy of the stimuli The same pathology is not observed for all exposure conditions which produce the same threshold shifts of the cochlear microphonic This relation of the observed pathology is consistent with the finding that peak pressures play such an important role in acute acoustic trauma

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NOISE-INDUCED HEARING LOSS DIAGNOSIS, PRESBYCUSIS, SUSCEPTIBILITY*

Gordon D Hoople,

State University of New York,

Syracuse, New York

The diagnosis of noise-induced hearing loss is not a simple problem It would be convenient, indeed, if noise produced a hearing loss, the audiogram of which would differ materially from the audiograms of every other known cause of hearing loss Since this is not the case other factors in addition to an audiogram must be taken into consideration

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*Due to Dr Hoople s illness this paper was read by Dr Ben H. Senturia of St. Louis.

In the differential diagnosis of hearing losses, it is probable that the history given by the patient is one of the most important factors to be appraised Obviously, if there has been no exposure at all to noise, no matter what the audiometric curve may be, a demonstrated loss cannot be due to noise, however, if there is sufficient exposure to noise *and* hearing loss of the type usually found in patients who have been subjected to noise, then the demonstrated loss is probably due to this cause How comforting it would be if the last part of the preceding sentence could read "the demonstrated loss is surely due to noise" It is rare, medically, that one can be as positive as this This is because, with man and his diseases, the blacks and the whites do not stand apart, they are mixed Thus, one is confronted with the problem of ascertaining the amount of black and the amount of white in the presenting grey This problem comes to the fore when patients who have been exposed to noise, and who have a demonstrable loss, are brought before juries or compensation referees, and doctors from one side testify there is little hearing loss due to noise, and medical testimony from the other side expresses the opinion that most of the loss is due to noise Both sides admit they are talking in terms of grey, but they cannot agree on the percentages of the black and white which make up the grey, thus, it is that judgment must come into this picture when all of the facts of a given case have been brought to light

With this in mind, there are several aspects in the history of such patients which can lend weight to one decision or the other

1 The character of the onset of any hearing loss This symposium is concerned with industrial noise-induced hearing loss Sudden explosive noises are not included These sudden noises, if they are sufficiently loud, often produce a sudden hearing loss With industrial noise, the opposite of sudden explosive noise, it is conceivable though *highly* improbable that an exceptional susceptibility might account for a permanent sudden hearing loss This would be most unusual I have never seen such a case and have never heard of one, and inquiry among my colleagues yields a like experience, hence, there must be a history of gradual loss Usually the discovery of such a loss is made by the family or friends of the patient The loss is so gradual (when at last it begins to be a slight handicap) that the patient does not realize its presence

2 Associated vertigo Sudden loss may have accompanying vertigo, but there is none with chronic noise-induced loss

3 Accompanying tinnitus If this is present it is more than likely that one can elicit a history of an increase of its intensity late in the day of exposure, or in the following early evening hours It is also likely that a worker will state that his hearing seems to be poorer during these same time periods

4 There is always some hearing loss in both ears, although one ear may have sustained greater loss than the other Careful inquiry into the exact nature of the individual's work pattern and his exposure to noise may reveal a cause for greater loss in one ear than the other In the great majority, however, the loss is essentially the same in both ears

5 Further inquiry as to the patient's work conditions may suggest reasons why a loss is present Much noise in small enclosures or rooms with reverberating walls will cause more loss than similar noise in open spaces Work with pneumatic hammers, pneumatic drills, drop forges, riveting guns and chipping tools are notable for their contributions to hearing loss If further evidence of work conditions are available such as the overall intensity of the noise, its spectral characteristics, and the length of time an individual has been exposed to these noise conditions, judgment can be more correctly given as to the cause of a worker's hearing loss The time factor is most important Without considerable time spent in noise there will be no permanent loss In truth, there is no such thing as a hazardous noise in industry There is only hazardous noise *exposure*

6 It should be obvious that inquiry should be made for other possible causes of hearing loss in a given patient This inquiry should be directed, not only to the ears but also to any diseases or accidents which might be contributing factors to a hearing loss This might prove to be time consuming, but the history should go even further to include the hearing experience of all known relatives

From these points it can be readily seen that the history can contribute much toward a correct decision as to how much black and how much white there may be in a given case, and certainly shows that a careful history should never be omitted in assaying a suspected noise-induced hearing loss

The second tool in the hand of the diagnostician, and one which is invaluable in arriving at a correct decision, is the examination of the patient as well as the assessment of his hearing Here, also, there are points of distinct value

1 For this discussion we will pass quickly over the general examination of the patient, both physical and laboratory, but this may elicit a reason or reasons for a hearing loss

2 Theoretically, the examination of the ears, nose and throat should be normal in an individual with noise-induced hearing loss for exposure to chronic noise causes no injury to these parts, *i e*, there should be a normal drum head, but this is almost tantamount to saying that noise cannot cause hearing loss in an ear which has been the victim of previous disease While a well marked conductive loss can give some protection, industrial noise can and does cause changes in the cochlea of such ears In this area are some of the most difficult decisions an otologist has to make, *i e*, how much of the loss of hearing that is present is due to noise and how much is due to the concomitant conductive lesion

3 More substantial aid is given the examiner by hearing tests Significant findings include

a Bone conduction readings which parallel the air curves Should a bone-air gap be present some additional cause for the loss other than noise must be in the picture

b The air curve will show a loss which is greater at 4,000 c p s than any other frequency in almost every instance This is always true when assaying an early loss It is probably so in approximately 98 per cent of all cases, even when long exposure is known to be in the picture (see Fig 1)

c The frequencies below 500 are rarely affected If hearing at these frequencies is depressed, search should be made for other causes

	100	250	500	1000	2000	4000	6000	8000	11000
A S	0	–5	–5	–5	–5	40	30	20	
Air—									
A.D	0	0	0	0	0	40	35	25	

Fig 1

RIVETER

	100	250	500	1000	2000	4000	6000	8000	11000
A.S	5	10	15	55	55	60	50	60	..
Air—									
A.D	15	15	20	65	65	60	45	55	---

The reading at 4 000 c.p s in the Left Ear is the greater

CHIPPER

	100	250	500	1000	2000	4000	6000	8000	11000
A.S	5	10	35	50	50	50	45	60	..
Air—									
A D	10	20	40	40	55	60	50	50	—

The reading at 4 000 c p s in the Right Ear is the greater

MACHINE HAMMER

	100	250	500	1000	2000	4000	6000	8000	11000
A.S	–10	–5	0	20	65	85	—	..	
Air—									
A D	–5	0	0	15	70	90			..

Fig 2

d When there has been lengthy exposure to certain noises and the resultant hearing loss shows a fair amount of change at 1,000 c p s , and even at 500 c p s the audiometric dip at 4,000 c p s tends to level out, or even be eradicated, but the audiogram still is indicative of possible noise induced etiology (see Fig 2)

e Concomitant disease and presbycusis are two important causes for an eradication of a notching 4,000 c p s audiogram by causing even greater losses at the 6,000 and 8,000 frequencies Diseases and toxic conditions which may depress the hearing in this manner are syphilis, dental, tonsillar and prostatic diseases, alcohol, nicotine, quinine, the salicylates, the mycins (antibiotics), senile vascular changes, allergy, etc (see Fig 3) (Example losses above 4,000 c p s are the greatest)

PRESBYCUSIS

	100	250	500	1000	2000	4000	6000	8000	11000
A S	5	10	10	10	10	20	50	60	
Air—									
A.D	0	5	5	5	10	30	60	65	

DISEASES

	100	250	500	1000	2000	4000	6000	8000	11000
A.S	35	40	50	55	60	55	65	70	–
Air—									
A D	40	35	45	50	60	65	60	70	

ALLERGY

	100	250	500	1000	2000	4000	6000	8000	11000
A S	25	25	30	35	50	60	70	75	
Air—									
A D	30	25	35	35	45	60	65	70	

Fig 3

f Primarily the audiometric findings must be stable Three audiograms, each taken one week apart and at least 40 hours after the last exposure to noise, must show no appreciable variation This should be a requirement for establishing a base line for noise-induced hearing loss This practice, if adopted, rules out any temporary threshold shift of hearing This temporary threshold shift is known to exist in all involved ears during and shortly after exposure to noise Likewise, this practice will establish the persistent hearing loss present after 40 hours, from the last exposure Any change between the persistent hearing loss and a later determined permanent loss will be minimal

g Repeated audiograms will be important evidence in ruling out malingering or a false claim that a loss due to disease is due to noise Sometimes a single audiogram will do this (see Fig. 4). (Example: unilateral loss claimed to be due to chronic noise exposure).*

PRESBYCUSIS

Presbycusis has been mentioned above as a complicating factor in interpreting audiograms when noise inducted hearing loss is suspected. Some loss of sensitivity at some frequencies is to be expected as the normal result of the process of ageing. This has been shown in many studies, but those of Bunch,[1] the World's Fair,[2] the San Diego Fair,[3] and the Wisconsin State Fair,[4] are in reasonable agreement as to the hearing loss which is present due to ageing. It is generally agreed that hearing losses due to noise and presbycusis are additive.[5] The Z24-X2 Committee of the American Acoustical Society pointed out that both presbycusis and noise-induced hearing loss are "intra-cochlear deafness." They are indistinguishable microscopically. Both involve the permanent loss of some sensory cells and their nerve fibers. This Committee felt there was no reason to suppose that presbycusis protects the ear from further injury by noise, nor does it make the ear more sensitive to injury.

	100	250	500	1000	2000	4000	6000	8000	11000
A.S	0	0	0	5	0	0	5	10	–
Air—									
A D	45	50	60	70	60	50	75	80	—

The loss at 4 000 c.p s is considerably less than at 500 and 1 000 c.p s

Fig 4

An allowance for the loss, due to presbycusis, has been suggested for appraising the hearing loss in workers over 50 years of age. For the frequency 2,000 c p s, this loss on the average amounts to about 5 db in the sixth decade, and 10 db in the seventh. The losses at 4,000 c p s on the average are about 10 db and 20 db respectively, but there are large individual differences.[6]

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SUSCEPTIBILITY

That the human ear is susceptible to hearing loss by exposure to chronic noise has been known for years. Fosbroke's[7] article in *Lancet* was written 137 years ago, and this cause of hearing loss was probably recognized before this early date. How susceptible the ear may be, and whether or not some ears are more susceptible than others has been a debated subject for scores of years. The answer to the susceptibility question is relative rather than absolute. Barr[8] commented that of 100 boilermakers examined by him who had worked at this trade at least four years, none had normal hearing. Boilermaking certainly is an occupation which has a hazardous noise exposure, particularly when a worker is subjected to the reverberating sounds inside a boiler. What about less hazardous noise exposures?

Most writers on the subject of noise-induced hearing loss state that some human ears are more vulnerable than others,[9, 10] but no one to date has fashioned a statistical table attempting to delineate what percentage of all ears are, for instance, highly susceptible, very susceptible, moderately susceptible, barely susceptible, etc. If one dared prepare such a table it would have to be for one certain well described and accurately measured noise, existing under known conditions, to which would have to be added the known length of exposure. It is obvious that there would have to be thousands of tables to have any value at all, for the variables are multidimensional, even then such tables would be valueless for protection purposes, for they could not delineate a particular individual and indicate that he would be one of the highly susceptibles.

There has been much searching for a reliable test for sensitivity. Everyone acknowledges its desirability, but to date none of the advocated tests have been validated by practical experience. Tests have been devised, based on marked loss of hearing immediately after exposure to loud noise[11] or on the basis of slow recovery from such a temporary threshold shift,[12, 13, 14, 15] but persistent and *permanent* hearing losses do not necessarily follow a temporary threshold shift. Here again variables are multidimensional Like variables are present for the Lawrence and Blanchard[16] aural harmonics test for susceptibility

Glorig has stated from the examination of many thousands of industrial hearing records there are only a few persons who are highly susceptible to noise For the present, then, it seems expedient and wise to employ monitoring audiometry in all industrial situations where a noise problem exists, and to separate from their noisy environment those workers who show significant hearing losses on several 40 hours audiograms This will protect both the employer and the employees, and is a safe procedure to use till further studies and further statistics can show that a valid susceptibility test is or is not possible.

SUMMARY

The problem of the diagnosis of noise-induced hearing loss is difficult, because losses due to causes other than noise may be present A detailed history of a patient may furnish valuable information. The examination of the patient, together with a study of his audiograms, can give further light

Presbycusis is a known complicating factor, and an allowance for its presence should be made in workers over 50 years of age

Susceptibility to noise is as yet an unsolved problem No predictive tests have been validated The answer to susceptibility is relative rather than absolute

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EAR PROTECTION *

J Zwislocki,†

Harvard University,

Cambridge, Mass

Most probably, even those of you who do not take any active part in solving the noise problems must have noticed that these problems have been discussed, if not exhaustively, at least extensively at many times and at many places We have a journal entitled "Noise Control," and a "Handbook of Noise Control" Numerous committees and meetings are devoted to noise problems Possibly some of you might think that we are making too much noise about noise, however, even those who do think so must admit that, one way or the other, we do have too much noise, and that something should be done about it

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†Now at the Office of Research in Special Education and Rehabilitation Syracuse University Syracuse New York.

I consider myself fortunate to have been given the opportunity of discussing one of the means of combating noise This gives me the feeling of usefulness, of doing something positive instead of just complaining Of course I must admit that if nobody complained about noise, and there are still some left who do, I would have no business talking about ear protection

Now, back to the subject I doubt that anybody considers the personal ear protectors as the most desirable means of noise control There are probably no more people who want to wear earplugs or earmuffs than there are people who want to wear eyeglasses Although not the most desirable, personal ear protectors are probably the most versatile, effective and the most economical means of noise control This does not imply, of course, that other means should be happily abandoned In many situations we have to apply every trick we know to keep noise at a tolerable level, and sometimes we run out of tricks In addition, personal ear protectors are always somewhat uncomfortable and cumbersome, and, maybe most important, they do not improve speech communication by any considerable amount, except when the transmission occurs through an earphone, and the earphone with its socket serves as an ear protector

The best means of noise control is undoubtedly to stop the noise right at its source That means, not to make any noise at all Unfortunately, we have not been very successful in this endeavor and, according to Dr Knudsen, noise is increasing at a rate of one db per year It seems, therefore, that ear protectors are here to stay for a while, and they should be considered at an equal level with the other tools of noise control

I could devote this time to showing you pictures of various types of ear protectors, but I doubt that in this way you would learn much more than the fact that there are many types of ear protectors I shall try rather to synthesize our knowledge on the problem of personal ear protection, discuss the basic requirements, the possibilities, and the main trends in recent design

It is possible to classify the ear protectors according to their position relative to the ear We have four kinds ear-plugs, semi-inserts, earmuffs, and the helmet Earplugs are secured in the ear canal and usually do not require any additional means of support (see Fig 1) Semi-inserts are placed at the entrance to the ear canal and are usually supported by a headband Earmuffs cover the outer ear like an earphone mounted in its socket or cushion Helmets cover the whole head, or at least most of it

I am going to omit the semi-inserts, because there are none on the market, and the helmets, because I feel that at present they do not offer any acoustical advantage

Now, what is expected of ear protectors? *First,* they should attenuate acoustic noise to a safe level, whatever that level is *Second,* they should be comfortable, or, let us be more realistic and say, they should not be too uncomfortable *Third,* they should not have any toxic effect on the skin There are further requirements that are more or less compelling, depending on the situation They concern the interference with speech communication, the ease with which the ear protectors can be handled, the sanitary aspect and the economic aspect Some of these requirements are in conflict with each other, and only compromise solutions appear possible The best known incompatibility is between sound attenuation and comfort Another one is between attenuation and speech intelligibility, although this one is more apparent than real, but let us start with the first requirement, *i.e.*, sound attenuation

How much sound *should* be attenuated?

This is certainly a pertinent question Unfortunately, I cannot answer it, at least, not at this time, because there are probably as many optimal attenuations as there are situations in which the use of ear protectors appears advisable and maybe even more, maybe almost as many as there are people

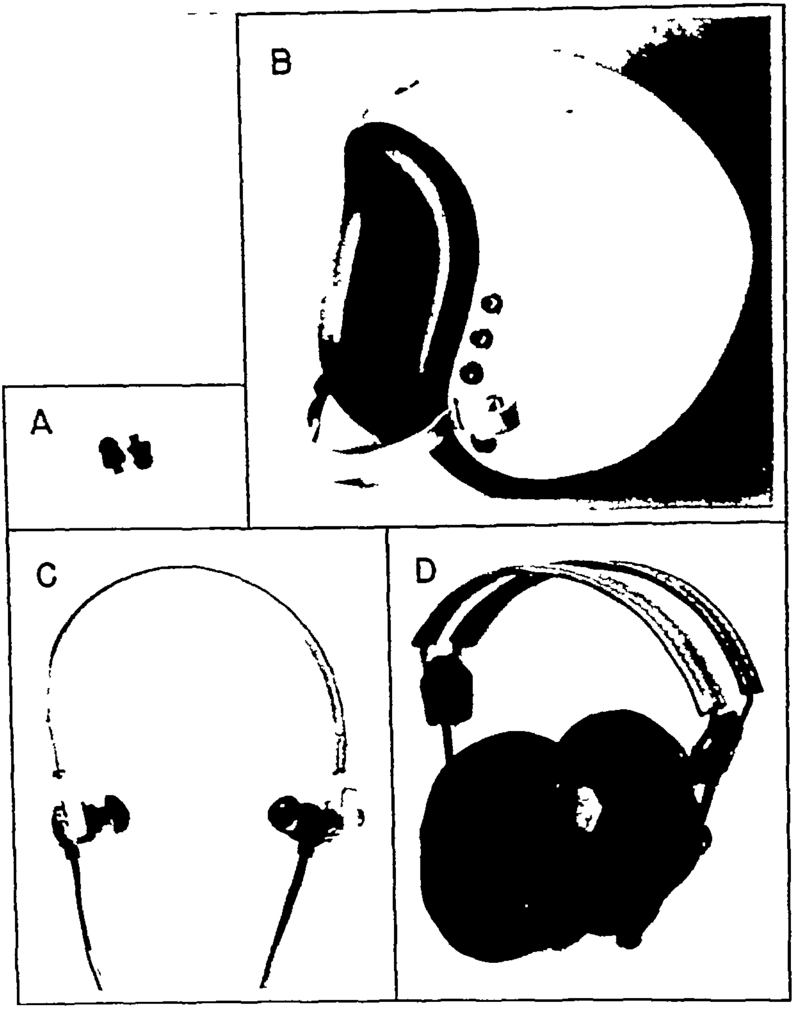


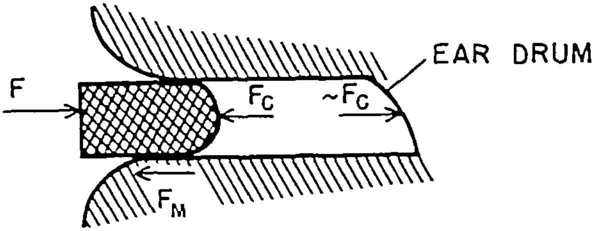
Fig 1. Four Kinds of Ear Protectors.

involved In other words, this is a policy question at present, and not a scientific question, and therefore not for me to answer I can answer, however, a somewhat related question how much sound *can* be attenuated? This question is restricted, of course, to ear protectors that can be worn either in the ear canals or on the head By enclosing a man in a cell of concrete, higher sound attenuations than those I am going to speak of can be achieved

When an earplug is inserted into the ear canal, the sound can still reach the inner ear on three pathways Because of the flexibility of the skin lining the external auditory meatus, sound waves can produce a vibration of the earplug as a whole The vibration is controlled at low frequencies by the stiffness and the viscosity of the skin and, at high frequencies, by the inertia of the earplug The sound can also penetrate the ear through deformation of the earplug—here the stiffness, density and viscosity of the material become important Finally, sound can reach the inner ear by traveling around the earplug, either via bone or via soft tissue or both I am going to refer to this channel as body conduction

For low frequencies, the forces acting on an earplug secured in the ear canal may be schematized as shown in Fig 2 The force F symbolizes the external sound pressure multiplied by the effective area of the earplug The force F_C is equal to the produce of the sound pressure generated in the ear canal and of the crosssectional area of the ear canal Finally, F_M denotes the resultant opposing force developed in the skin lining The law of the equilibrium of forces requires that F be equal to the sum of F_C and F_M It is easy to see that the sound attenuation grows with the ratio between F_M and F_C This ratio is determined to a large extent by the properties of the skin lining and by the volume of the enclosed air, in addition to the acoustic impedance that can be measured at the ear drum It is, therefore, an anatomical constant and cannot be altered to any considerable degree The only thing we can do in order to improve the sound attenuation is to make the earplug itself impervious to sound Various solutions are possible, and I am going to discuss them a little later when I show you some typical designs

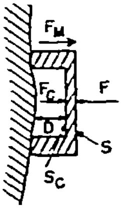
Let us now consider the factors determining the sound attenuation provided by earmuffs Although earmuffs look considerably different from earplugs, their acoustic action is similar The vibration of a good earmuff is controlled by the flexibility and the resistance of the skin under the cushion, and by the inertia of the earmuff The sound attenuation depends mainly on three factors the mechanical properties of the skin, the mass of the earmuff, and the depth of the



$$F = F_M + F_C \quad ; \quad \frac{F}{F_C} = \frac{F_M}{F_C} + 1$$

$$\frac{F}{F_C} = \frac{F_M + F_C}{F_C} \quad ; \quad A = \frac{p}{p_C} \cong \frac{F}{F_C} \cong \frac{F_M}{F_C}$$

Fig 2 Schematic drawing of an earplug in the ear canal and the relations among the acoustic forces acting on the earplug



$F = F_M + F_C$

$F_M = Z_M u$

$F_C = Z_C u$

$F = u(Z_M + Z_C)$

$F_C / F = Z_C / (Z_M + Z_C)$

$F = Sp$

$F_C = S_C p_C$

$p_C / p = S / S_C \times Z_C / (Z_M + Z_C)$

$Z_C \sim S_C^2 / V \, , \; V = S_C D$

$Z_C \sim S_C / D$

$$A = p / p_C \sim Z_M D / S$$

Fig 3 Schematic drawing of an earmuff covering the ear and the relations among the acoustic forces acting on the earmuff

earmuff The situation is described by the schematic drawing and the formulas of Fig 3, however, I do not want to go into algebra, and shall state only that, when a high attenuation is desired, the earmuff should be deep and cover as small an area of the head as possible Of course, in practice there are limits in both respects A deep earmuff becomes cumbersome, and an earmuff that covers too small an area of the head may exert painful pressure on the pinna and become uncomfortable

When an earplug is inserted into the ear canal, the sound can still reach the inner ear on three pathways Because of the flexibility of the skin lining the external auditory meatus, sound waves can produce a vibration of the earplug as a whole The vibration is controlled at low frequencies by the stiffness and the viscosity of the skin and, at high frequencies, by the inertia of the earplug The sound can also penetrate the ear through deformation of the earplug—here the stiffness, density and viscosity of the material become important Finally, sound can reach the inner ear by traveling around the earplug, either via bone or via soft tissue or both I am going to refer to this channel as body conduction

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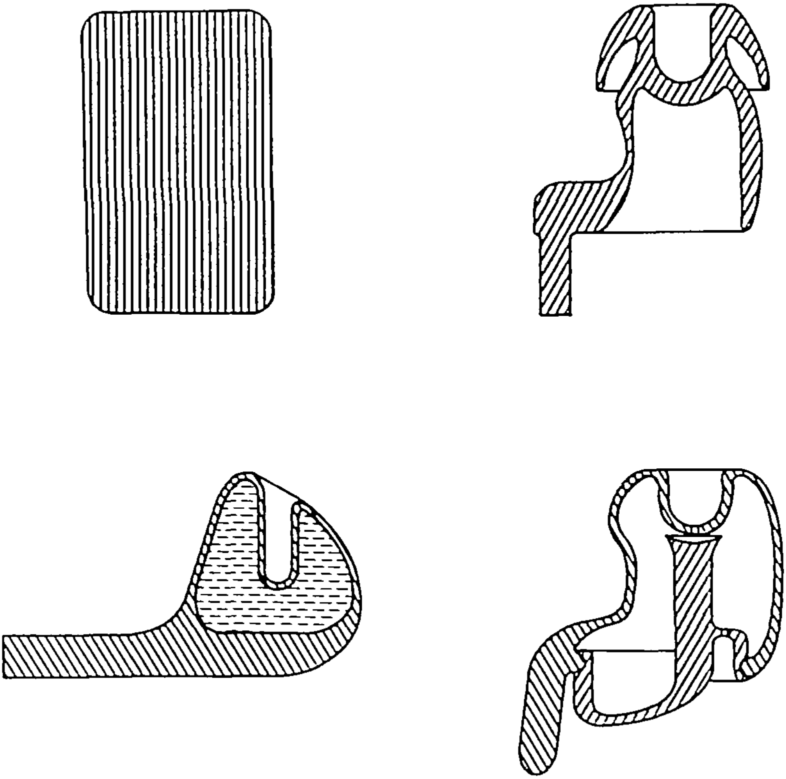

Fig 5 Four Types of Earplugs.

Regarding a few models of commercial ear protectors, Fig 5 shows four earplugs which, I think, are typical The earplug in the upper left corner is a cylinder of wax and cotton It can be shaped by hand to fit the ear canal Ear-

Even if the earplug and the earmuff were ideal in the sense that no sound would be transmitted through them, the sound could still reach the inner ear by body conduction, as I mentioned before Body conduction constitutes the absolute limit of sound attenuation that can be expected from ear protectors

The body conduction threshold in a free field has been measured recently, and I am going to report on it in the coming meeting of the Acoustical Society in New York Here I can only show you some of the experimental results

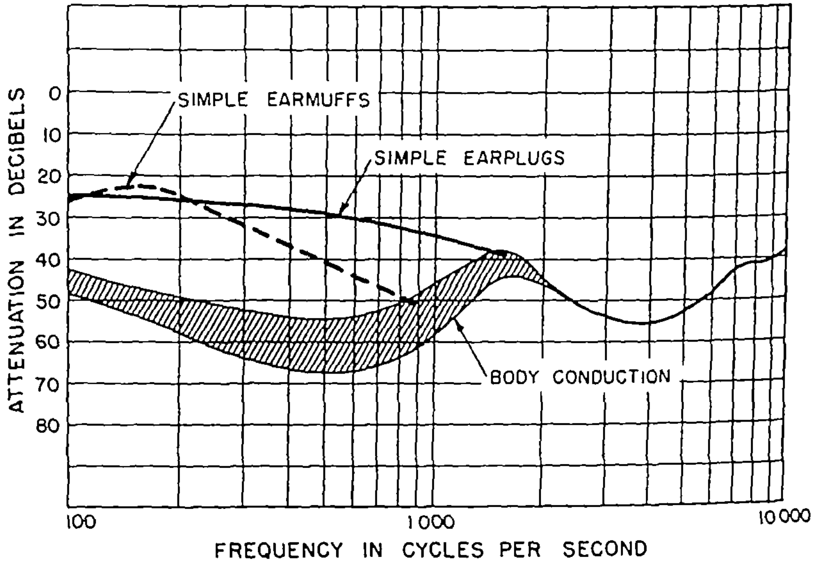

Fig 4 Air conduction (lower curve) and body conduction thresholds of audibility in a free sound field. The shaded area indicates the uncertainty due to the effect of the occlusion of the ear canal on bone conduction

The zero level in Fig 4 refers to air conduction threshold in a free sound field The lowest curve in the diagram is the body conduction threshold in a free field as measured recently The shaded area indicates the uncertainty caused by the effect of the occlusion of the ear on bone conduction It is well known that the occlusion of the ear canal improves bone conduction at low and medium frequencies when tests are per-

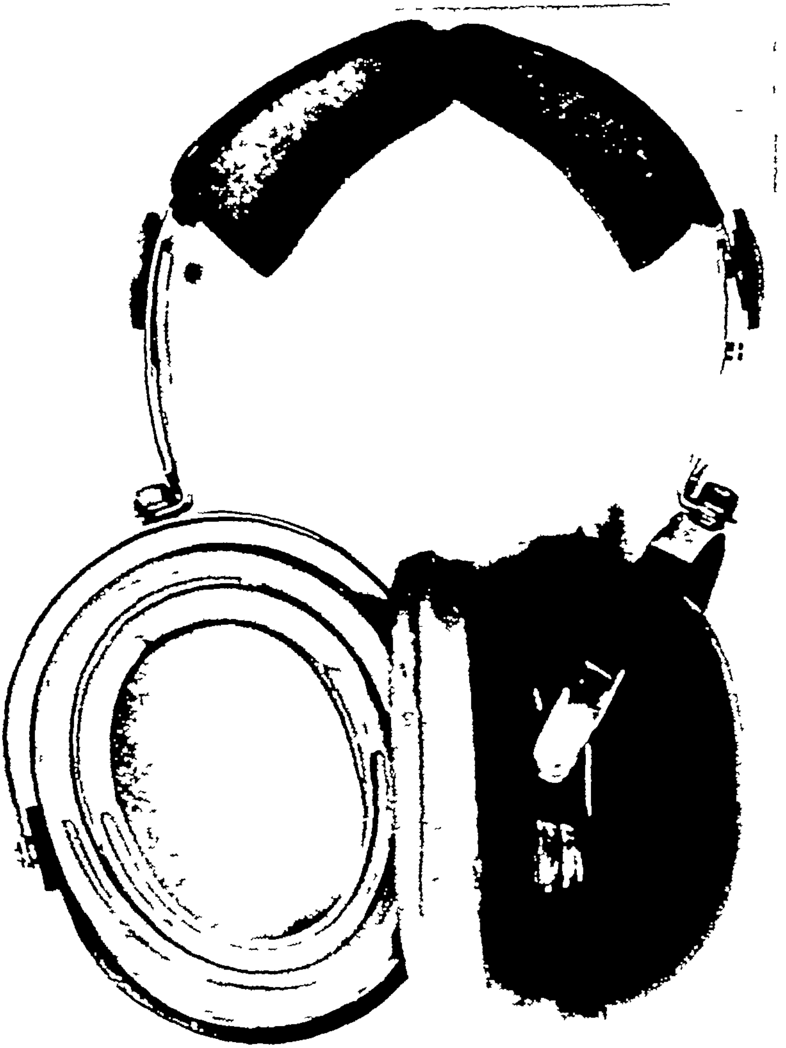

Fig 7 A Set of Typical Earmuffs.

being inserted into the ear, and facilitates the insertion by stiffening the earplug along its longitudinal axis In addition, a back wall increases the sound attenuation at high frequencies In some of the models the front and the back wall are perforated so that the earplug acts as a low-pass filter The advantages of such a decreased attenuation at low frequencies is still debated plugs of this type are very comfortable and attenuate noise pretty well They have the drawback, however, that they cannot be washed and, consequently, have to be thrown away after being used only once Their sticky surface has the tendency to accumulate dirt

The earplug in the upper right corner consists of rubber or plastic Because of its elasticity it adapts to the shape of the ear canal while being inserted It attenuates noise very well, is washable and can be reused many times There is one difficulty in order to obtain a high attenuation, the material of the earplug must be sufficiently stiff When the earplug is too stiff, however, it becomes uncomfortable, so that only a compromise solution appears possible

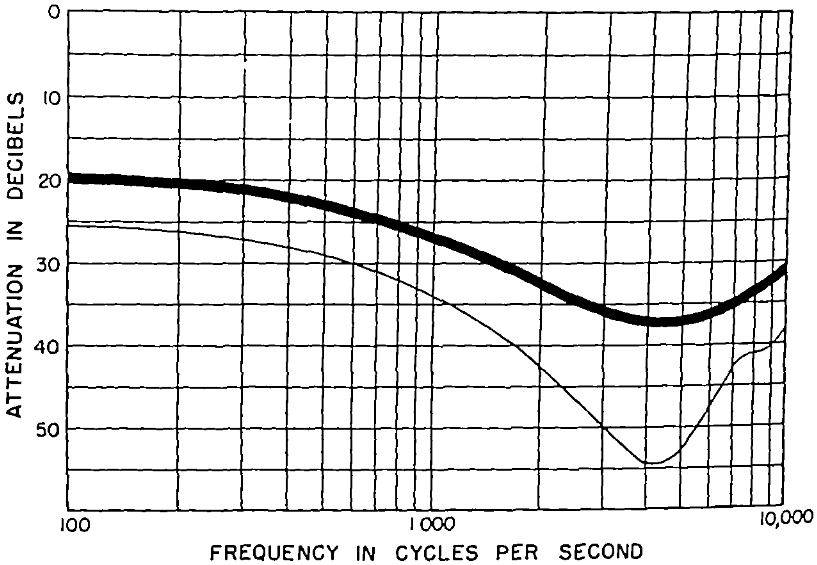

Fig 6 An approximate attenuation characteristic of the four earplugs shown in Fig 5 (heavy line) The thin line shows the theoretical upper attenuation limit for simple earplugs

The earplug shown in the lower right corner of Fig 5 is basically similar to the earplug discussed in the preceding paragraph, but it has some additional features It contains an internal core made of a stiffer material than the outer shell This core touches the front wall while the earplug is curve shows the theoretical upper attenuation limit for simple earplugs

Fig 7 shows a set of typical earmuffs The earmuffs are designed very much along the lines mentioned above they are deep, enclose a large volume of air, cover a rather small area of the head, and consist of a hard shell and a sealing cushion of foam rubber The sound attenuation thus provided can be seen in Fig 8 (heavy line), together with the theoretical limit (thin line) The foam rubber cushion may be considered a weak point in the design of the earmuff Recently developed cushions with high internal viscosity or with low volume compressibility could further improve the attenuation at low frequencies

I would like to conclude on an optimistic note by predicting that within a few years we are going to have ear protectors which will attenuate sound up to the limit set by body conduction I hope that such ear protectors will be commercially available

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ESTABLISHMENT OF CRITERIA BASED ON THE CONCEPT OF NOISE EXPOSURE*

WALTER A ROSENBLITH,

Massachusetts Institute of Technology,

Cambridge, Massachusetts

This morning we have heard a discussion of the general topic of noise-induced hearing loss Thus far the emphasis

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*This work was supported in part by the U S. Army (Signal Corps) the U S. Air Force (Office of Scientific Research Air Research and Development Command) and the U S. Navy (Office of Naval Research)

The earplug in the lower left corner is probably of the most recent design It combines some features of the wax-cotton earplugs with those of the permanent elastic earplugs It consists of a malleable core covered by thin elastic walls The internal tube, which is open at one end, increases the adaptability to the ear canal Within certain limits the earplug is malleable like the wax-cotton earplugs At the same time it has sufficient resiliency to follow temporal changes of the cross-sectional area of the ear canal It can be washed and reused

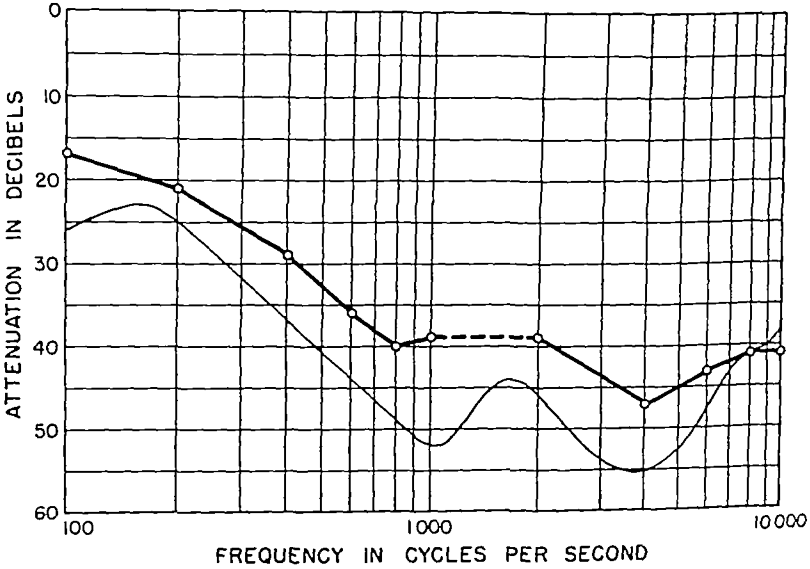

Fig 8 The attenuation characteristic of the earmuffs of Fig 7 (heavy line) and the theoretical upper attenuation limit for simple earmuffs (thin line)

All the earplugs of Fig 5 provide approximately the same sound attenuation At least, the differences among the earplugs, found in one laboratory, are of the same order of magnitude as differences in results obtained for the same earplug in different laboratories It seems reasonable, therefore, to pool the data obtained for the four earplugs The thick curve of Fig 6 was obtained in this way The thin the effects of noise upon exposed humans than we can predict the genetic effects of atomic radiation upon future generations Just because we can, under the right conditions, make fairly reliable audiometric measurements of man's hearing does not mean that we can ignore the basically multivariate and statistical nature of the after-effects of any exposure, whether this exposure be to acoustic, electromagnetic, or atomic radiation There are no convenient single numbers that summarize both the exposure and its over-all effects, and this is, to me, what Dr Hoople means when he writes "the relations of hearing loss to noise exposure are multidimensional "

THE SEARCH FOR AN ECONOMICAL DESCRIPTION OF THESE RELATIONS

It appears, then, that we must pick and choose a set of variables in order to describe noise exposure and its effects upon the hearing of even quite well-defined exposed populations Selection of the variables is determined in part by our ability to measure certain quantities more accurately and more easily than others, in part by our value judgment of what aspects of human hearing are most important, and finally, by our desire to obtain simple relations between reasonably economical descriptions of both exposures and after-effects If these relations between quasi-engineering variables make sense in the light of what we know about possible mechanisms, so much the better

It is in this context that the progress of research on the after-effects of noise exposure and of criterion guessers must be evaluated We have come a long way since the period in which noise exposure was characterized by an over-all level, read on one of the early sound-level meters, we are, nevertheless, far from being able to give an adequate description of the acoustic environment in which a drop forger spends his working life We have become keenly aware of the fact that exposures to even quite steady-sounding noises need to be characterized by spectrum, duration, and by what might be called a statistical description of temporal fine-structure

These considerations give us a glimpse at the complexities has been upon the technical problems that still remain to be solved The speakers who preceded me stressed for our benefit the difficulties that are encountered in the collection of data and the uncertainties of interpretation that need to be resolved By way of contrast (and not with any intention of being less honest) I shall try to emphasize, in rather general terms, the knowledge that we have already gained Consensus is obviously needed before we are ready to go about setting criteria or standards realistically Unless there is significant agreement among the presumably best informed technical people we have no basis for the social standard of judgment that a criterion represents In the United States alone, several criteria have been suggested within the past decade, and the same seems to have happened in other countries This plethora of suggested criteria reflects to some extent the complexity of the task involved, whether we attempt to set standards for maximum allowable concentrations of chemical poisons, for exposure to radiation, or for exposures to noise

Recently (1956) the U S National Academy of Sciences published a series of summary reports on "The Biological Effects of Atomic Radiation" The distinguished committee on the Genetic Effects of Atomic Radiation tried to put before the general reader some of the complications that must be faced before decisions can be reached or recommendations for the general welfare made The scientist-citizen has to be willing to make rough estimates in areas in which his knowledge is far from certain He may then have to weigh the outcome of these technical considerations, with their attendant uncertainties, against considerations of national security and international relations The role of the scientific statesman is thus hardly one for which graduate or even postgraduate study prepares

THE RELATIONS OF HEARING LOSS TO NOISE EXPOSURE INVOLVE MANY VARIABLES

Fortunately, the risks that concern us in this conference are less serious than those that result from exposure to atomic radiation, furthermore, we can more easily assess some of to these questions or at least decisions regarding them would have to be forthcoming before standards or criteria could be stated In the years that have passed, informed scientific opinion has come to feel that as long as man's hearing for everyday speech, under everyday conditions, remains protected, we are successfully preventing noise-induced hearing losses from becoming a serious handicap We have said enough about the difficulties of specifying noise exposure The last two decades have seen much progress in the spectral analysis of noise, it is to be hoped that in the years ahead comparable progress will be made in the analysis of noise exposures Certain promising beginnings have already been made, and the necessary electronic equipment and computational facilities are at least in principle available

The Z24-X2 report asked "What percentage of the people exposed should a standard be designed to protect?" This amounts to picking a cut-off percentage in a statistically determined situation and is equivalent to saying that a given criterion entails a risk of a serious handicap in X per cent of the exposed population The representative of a state government who testified before the Z24-X2 committee reminded us gently that such a position was politically impossible in a democracy, where one has to aim at protecting everybody Without entering into an argument on issues of social philosophy, let us point to the role of programs of hearing conservation and in particular to monitoring audiometry It is by such programs that the highly susceptible individuals who are working in noise-hazardous areas can be identified and transferred to locations where there is less risk to their hearing Thus criteria and preventive medicine can combine to protect practically everyone

Two Examples of Criteria for Noise Exposure

From what precedes it should be clear that a particular criterion represents a multifaceted compromise it assumes a certain population and a certain level of acceptable risk, it is, in general, accompanied by a certain hearing conservation program, and it makes certain assumptions about future noise exposures (most often it assumes that they will be more or less identical with those that prevail today) By of defining the effective exposure stimulus Its specification depends, at least in part, upon the kind of after-effect in which we are going to be interested, hence, we need agreement upon a valid and yet reliably measurable estimate of man's auditory capacities Given our general concern with human communication, it seems reasonable to settle upon man's ability to communicate by speech This is not the place to discuss our present ability to make such measurements in a nonlaboratory environment, or even the possibility of predicting, by pure-tone audiometry, man's ability to discriminat speech, but we should emphasize that pure-tone audiometry will continue to have value from the viewpoint of preventive medicine for a long time to come

Finally, we must face the problem of just how homogeneous our populations are with respect to exposure and to the variety of other variables (such as military service, education, and so on) that are at least partially correlated with the response variables that we have chosen

The socially necessary task of predicting the effects of exposure upon whole populations bears little resemblance to prediction in the classical stimulus-response paradigm There the stimulus is something that happens "here and now", it can be assumed that the experimenter has been able to uncouple his subjects sufficiently from their distant and recent past and that post-experimental events will have little influence upon the subject's response behavior Even in classical psychophysics these assumptions are not always justified, here, they are completely unrealistic Here, noise exposure stretches over a man's working life-time and may well include significant contributions to this exposure from his military service, from his acoustic environment while he travels to his job or about this globe, and from his addiction to loud music—to name just a few of the possible hazards These uncertainties in the specification of the exposure make for increased variability, just as presbycusis and quasi-social factors do

WHOM SHOULD CRITERIA BE DESIGNED TO PROTECT?

In the section entitled "Conclusions" the Z24-X2 report formulated three questions The committee felt that answers basis for a nomogram that permits the computation of equivalent exposure times

Let us now pass from this example (in which we deal with a rather well-defined population, in which we are preoccupied primarily with "jet-type" noise, and in which the statement of criteria is accompanied by a well-designed hearing conservation program) to a document that aims at less clearly defined situations In its recent "Guide for Conservation of Hearing in Noise" the Subcommittee on Noise in Industry states

"At the present time our knowledge of the relations of noise-exposure to hearing loss is much too limited for us to propose safe amounts of noise-exposure We can, however, point to certain noise levels that indicate when it is advisable to initiate hearing conservation programs These levels will not be general because a different level is needed for different types of noise and different schedules of exposure The hearing conservation level that we now specify tentatively applies only to years of exposure to broadband steady noises with relatively flat spectra It does not apply to short exposures, and, above all, it does not apply to impact noises or narrow-band noises This tentative hearing conservation level is stated as follows

"If the sound energy of the noise is distributed more or less evenly throughout the eight octave bands, and if a person is to be exposed to this noise regularly for many hours a day, five days a week, for many years, then if the noise level in either the 300-600 c p s band or the 600-1200 c ps band is 85 db the initiation of noise-exposure control and tests of hearing is advisable The more the octave-band levels exceed 85 db, the more urgent is the need for hearing conservation"

These two statements are not unlike in philosophy and general approach, and they do not differ much in terms of the actual numbers that are involved, but it would be unwise to conclude that 85 db is "it," and that there is not room for different compromises, for different cuts of the criterion-pie If your situation permits you to "fix" other aspects of noise exposure you may want to state your criterion in minutes per making all of these assumptions as explicit as we can, we cut the number of variables to the point where criteria can be set merely by specifying a few numbers[*]

Now I should like to quote from two recent documents to illustrate some of the points that have been touched upon in October, 1956, there appeared an Air Force Regulation entitled "Hazardous Noise Exposure" Its purpose was to establish a program for minimizing the undesirable effects of exposure to noise on Air Force Personnel In the section of the Regulation that deals with methods of controlling exposure to hazardous noise, "limits for noise exposure" are stated in this manner

"*a Limits for lifetime exposure* The limits for lifetime exposure to broad band noise are given in terms of the band pressure level for four octave bands The four octave bands are 300-600 c p s , 600-1200 c p s , 1200-2400 c p s , and 2400-4800 c p s In setting limits, it is assumed that the ears are unprotected and exposed continuously during normal work-hours over a period of 25 years The risk of damage to hearing is slight when the pressure level of a band does not exceed 85 db It increases as the band pressure level increases, and is excessive at 95 db Ear protection is recommended for continuous exposure to a sound pressure level above 85 db in any of the four octave bands It is mandatory for exposure above 95 db Ear protection may consist of reducing the noise level in the ear canal, reducing exposure time, or both "

There follows a statement on daily short-term exposures in which the so-called equal energy assumption[†] serves as a

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[*] As a matter of fact as long as the spectral and temporal character of noise stays in sufficiently narrow bounds two different exposures of equal duration could be compared on the basis of a single number only This single number (which could be the over-all level) carries along with it a whole host of hidden parameters

[†] According to this concept equal quantities of acoustic energy entering the ear canal are equally injurious regardless of how they are distributed in time assuming that the equivalent quantities of noise energy equal or exceed the hearing damage risk criteria. This is not the place to examine the evidence for this assumption or to discuss the ways in which it should be qualified At present it represents within certain limits a simple and yet quite conservative guide-line It would furthermore be instructive to compare and contrast the rationale for this assumption with the rationales expressed in statements from the NAS-NRC summary reports according to which the total dose of radiation is what counts this statement being based on the fact that the genetic damage done by radiation is cumulative and The concept of a safe rate of radiation simply does not make sense if one is concerned with genetic damage to future generations

6 Principles for Evaluating Hearing Loss (a report of the Council on Physicial Medicine) *J.A.M.A.*, 157 1408-1409, 1955 also *Noise Control*, Vol 2 11 13, Jan, 1956

7 Air Force Regulations 160 3 on Hazardous Noise Exposure Dept of the Air Force—Washington, Oct 29, 1956

8 Guide for Conservation of Hearing in Noise (prepared by the Subcommittee on Noise in Industry of the Amer Acad. of Ophthalmology and Otolaryngology), pp 1-24 1957, also *Noise Control*, pp 23-31, May 1957 also *Ind Med and Surgery*, Vol 26 185 192, 1957

PROF ROSENBLITH We will now have the discussion If you have a discussion as to a specific participant in this morning's program, direct it to him, if not, I shall try to direct it to the person most appropriate

DR. WARREN H GARDNER, (Cleveland, Ohio) I have been interested in the statement about the 4000 frequency dip and the probability that the dip can relate to acoustic trauma I am familiar with the audiograms of perhaps 200,000 to 300,000 children, and I have found quite a large number of 4000 frequency dips in children from ten to 18 years of age I should like to raise the question In an adult of 35 years of age, who has been working in a noisy place, how can we tell whether that 4000 frequency is due to acoustic trauma or whether he had that dip when he was 12 years old

PROF ROSENBLITH Will someone volunteer to answer?

DR SENTURIA I think Dr Hoople said something very wise about this precise problem in his paper

PROF ROSENBLITH Would you like to repeat them, or express your opinion?

DR SENTURIA No, I would like to express the opinion of Dr Gardner, that there are many persons under the age of 21—those who have not been exposed to noise, and who show 4000 cycle dips, and I, too, would like a further elaboration of this problem I wish that Dr Hoople were here, but since he is not, I would ask someone else in the audience, perhaps Dr Glorig, to elaborate

DR GLORIG I happen to be one of those persons who do not believe that there is a characteristic noise-induced audiogram It just so happens that when you look at audiograms of persons exposed to noise, the loss occurs first at 4000 cycles, day, or as a circle of yellow paint around a particular noise source, or even as a single number on the dial of a noise-level meter that weighs the frequency spectrum in an appropriate way

In summary, I should like to emphasize that, at present, we base our criteria on the concept of *noise exposure* in contradistinction to the previously emphasized *noise level* We feel that criteria or standards are, in the nature of things, a "package-deal" a given level of risk for a population whose age-structure, health conditions, and "working lifetime expectancy" in a given noise environment are more or less known, is coupled to hearing conservation and noise control programs of specified scope This ensemble of somewhat uncertain conditions is then held against the Z24-X2 trend curves (or similar information), the facts of speech communication, and against the backdrop of a prevailing social philosophy This is the process that yields criteria Men of science often feel ambivalent about their role in this process more than their nonscientific fellow-citizens, they are aware of the incompleteness of the technical information available, they know that by combining criteria with conservation programs we may protect human hearing at the cost of studying the after-effects of noise exposure more carefully, yet, if those who have expert knowledge will not advise in policy-making, they will fail to make their contribution to the functioning of a democratic society

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as just a guess, such as I have heard many times in court procedure, where the man was exposed to noise for five minutes "This is capable of producing a hearing loss, therefore, this man's hearing loss is due to noise" It is a great mistake to do this sort of thing You get yourself backed up in a corner many times, and can be made a fool of by the attorneys in this respect I don't think test of recruitment will give you any final answer

PROF ROSENBLITH Not being a medical person, may I say something about the way we have approached this problem We have talked here this morning about proability tables of hearing loss for given noise exposures Just as in mortality tables, there will be people who die early and people who die later, so for a given noise exposure, there will be a wide spread, and in this particular thing, you cannot, in my opinion, predict, unless you have a lot of extra knowledge Just as a hearing conservation program is also part of a diagnosis, because, in order to make a diagnosis, you want to have the kind of information that comes from controlling a man's hearing under conditions of noise exposure but I do not think that because there is a dip there, you can say it is noise-induced I think the answer to your question is, does it exist prior to it, whether you get an initial audiogram and then have an audiogram to follow, which will indicate what was there before the noise exposure

PROF ROSENBLITH The only time this morning that somebody talked about acoustic trauma was in connection with short exposures that give rise to something that we feel is more adequately described as trauma The slow, insidious, noise-induced hearing loss that we usually talk about, we would not like to confuse, at least in our present state of ignorance, with what is known as acoustic trauma Now, this is a preference, this terminology, but it helps us to keep our very limited number of facts straight

DR RICHARD E MARCUS, (Winnetka, Ill) In discussing the question of differential diagnosis, as raised in Dr Hoople's paper, and brought up again in the question of the 4096 dip, I wonder whether we might not consider some of these hearing conservation programs and screening surveys In essence we are finding the number of persons who have a hearing loss Then, we must use them as a point of departure for the individual hearing test, including the pure-tone audiometry, plus recruitment tests, and whatever other test we may be able to devise, to make the differential diagnosis The contour of the audiogram itself is not an indication of the diagnosis, but other hearing tests may well give us the clues that we are looking for

DR GLORIG I believe, that if you are going to make a differential diagnosis, you must have more than hearing tests You need physical examinations and history, particularly history of occupation I find that one of the facts most lacking in the histories that are taken in noise-induced cases is the history of the occupation of the individual This, then, allows for not having sufficient noise exposure, or no knowledge of what kind of noise exposure The making of a differential diagnosis is a difficult procedure and needs a great deal of experienced judgment on the part of the diagnostician It could not be done at the flip of a finger and hearing side by side with the sense of seeing What we learn from the study of vision can sometimes clarify our study of audition, and vice versa

The particular problems I shall discuss relate to the manner in which the eye and the ear respond to the intensity of light and sound

ELECTRICAL EFFECTS

Both the eye and the ear are what we call transducers, they convert energy from one form into another Although their principal function is to convert light and sound into nervous energy, they are also able to perform other interesting transformations Both these sense organs convert the energy of their respective stimuli into electrical energy, as demonstrated by the "electro-retinogram" in the eye and the "aural microphonic" in the ear These electrical phenomena turn out to be far more complex than was first supposed, but since we now know how to amplify and record the minute electrical potentials generated in the sense organs, we can use these potentials to study the action of the sensory transducers In the expert hands of my colleague, Dr Békésy, these methods have revealed important facts about the "electro-anatomy" of the complicated structures in the inner ear

Not only do the sense organs turn light and sound into electricity, but when we pass electric currents through these organs a sensation results Volta discovered this fact back in the year 1800, when he first connected some of his newly invented electric cells to metal rods inserted in his ears Some time later, E H Weber did a similar experiment, using his brother as the subject, but when he passed a current through the head, his brother saw a light This may have been the first instance of the production of what we now call a phosphene Actually, these early experiments were not very successful Fairly high D C voltages were used, and the result was too painful to bear repeating With smaller A C voltages it is quite possible to make a person hear a tone, or even a radio program I once filled my ear with salt water and connected the output of a radio set to an electrode immersed

CONTRIBUTED PAPERS

SESSION A

May 14, 1957

SOME SIMILARITIES BETWEEN HEARING AND SEEING*

S S STEVENS,

Harvard University,

Cambridge, Mass

One of the most vital and interesting facts about human beings is that they are equipped with sense organs through which they keep in contact with the world around them We perceive our environment through our sensory receptors, especially through our eyes and ears, and it is difficult to conceive how the human race could survive if we had no eyes or ears to inform us of what is happening at a distance These sense organs are small in size, but important in function They are so important that we organize great scientific efforts to study their nature and their behavior, and we come together in international conferences to tell of our discoveries, and to discuss our many unsolved problems

As members of this Conference we are, of course, more concerned with the ear than with the eye, but since these two organs constitute our principal means of perceiving the energy that is transmitted to us from distant objects, the eye and the ear have much in common and since, as scientists, we are deeply interested in the general laws of nature, we sometimes find it highly instructive to study the sense of

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*This research was carried out partly under Contract Nonr-1866(15) between Harvard University and the Office of Naval Research (Project Nr142-201 Report PNR-198) and partly under National Science Foundation Grant G-2668 Reproduction for any purpose of the U S Government is permitted.

hearing, the basilar membrane moves through a minute amplitude which is even less than the wave length of X-rays

Calculations reveal that the minute displacements needed to excite a sensation of hearing in a good ear are of the same order of magnitude as those that are produced by the thermal agitation of the molecules of the air itself To the ear with superior hearing, therefore, we may assume that any further increase in sensitivity would be of little use, unless one cared to listen to the banging of the molecules Like the eye, the ear can perceive almost as small a stimulus as nature can produce

DYNAMIC RANGE

Although, in evolving these transducers with their superb sensitivity, nature has pushed the thresholds down to where they are limited by the characteristics of the stimulating medium, nature has not forgotten that useful sense organs must also respond well to high intensities The dynamic range of the intensities to which these organs react is greater than a trillion to one

In order to measure such extreme ranges of energy, we commonly resort to the use of logarithmic scales, of which the decibel scale is an example We are all familiar with the use of decibels for the measurement of sound intensity, but it is interesting to note that the decibel is equally useful as a measure of light intensity By choosing appropriate reference levels, we have set up a common decibel scale for both light and sound in such a way that interesting similarities between the two senses are at once apparent[8]

The common decibel scale is shown in Fig 1 The reference or zero db levels are 10^{-10} Lambert for vision and 10^{-10} microwatt per square centimeter for audition Both of these reference levels are near the absolute thresholds of the two senses

First, we note that the luminance of the sun, our major source of illumination, is about the same number of decibels above threshold as is the intensity of a jet airplane with afterburner, which is probably the loudest sustained man-made noise yet produced Listening to the noise of such an airplane in the liquid I was able to hear the program, but it was quite distorted until a D C voltage was simultaneously applied to the electrode, then the speech and music became very clear My first thought was that this method of exciting the ear, which I have called the electrophonic effect, might prove an aid to the hard of hearing, but we soon discovered that an electrical stimulus becomes painful before it becomes loud enough to be useful When this sort of experiment is carried out on a normal ear, with an intact eardrum, the electric current probably does not excite the inner ear directly, but merely sets up audible vibrations in the skin[5]

In order to excite the cochlea directly, it is necessary to use a patient whose eardrum has been removed We once investigated 20 ears that lacked tympanic membranes[6] When stimulated by a sinusoidal electric current, 11 of these ears heard a pure tone, indicating that we may have been stimulating the cochlea directly Seven of the ears heard only a noise We may interpret the hearing of a noise as the sinusoidal current stimulating the auditory nerve directly In these experiments we sometimes stimulated other nerves—the facial nerve and the vestibular nerve—even though we were trying not to do so

SENSITIVITY

One of the most amazing things about our sense organs is their sensitivity The eye is such a sensitive device that the minimal energy that must reach the retina in order for a man to see is a mere half dozen quanta If the eye were much more sensitive it would probably do us little good, because light energy does not come in smaller than quantal packages

The sensitivity of the ear is no less surprising The ear is the most elaborate mechanical system in the human body At those frequencies where this complex mechanism is most sensitive, a sensation of hearing is produced when the eardrum moves through an amplitude that is less than the diameter of a hydrogen atom Under these circumstances, the motion of the basilar membrane is even less than that of the eardrum—approximately 100 times less At the threshold of

THE MEASUREMENT OF SENSATION

Although we use decibel scales to measure the intensity of the stimulus, we must realize that the decibel is not a measure of the sensation produced. By this I mean that a stimulus at 50 db. does not appear to us to be half as great as a stimulus at 100 db. It seems much less than half as great. The law that governs the apparent growth of sensation is not the logarithmic law that Fechner proposed more than a hundred years ago. If Fechner's law were correct, both brightness and loudness would be proportional to decibels. But when a person is asked to compare 50 db. with 100 db. he nearly always says that the 50 db. stimulus looks, or sounds, much less than half as strong. Most people report that the 50 db. stimulus appears to be only about one-fiftieth as great as the 100 db. stimulus.

During the years we have performed many different experiments to try to determine more precisely the law relating the magnitudes of the sensations of light and sound to their respective stimuli. Although different procedures give slightly different results, certain general principles are becoming clear. It is clear that we must replace Fechner's logarithmic law by a quite different formula, for the basic psychophysical law turns out to be a *power function*. For example, when people are asked to make direct quantitative estimates of the subjective brightness of a white light, the magnitude of their estimates is roughly proportional to the cube root of the physical intensity, and to me a most remarkable fact is that approximately the same law appears to hold when people are asked to judge the subjective loudness of a "white noise."

In order to fix a unit for the subjective scales which we use to measure brightness and loudness, we have chosen the stimulus level of 40 db. (see Fig. 1). Thus we define a *bril*, the unit of subjective brightness, as the brightness one experiences when looking at a luminance of 40 db., with the eye dark-adapted. Similarly, the unit of subjective loudness, the *sone*, is the loudness of a 1000-cycle tone at 40 db. (40 phons). On this scale, a loudness of 2 sones sounds twice as great as a

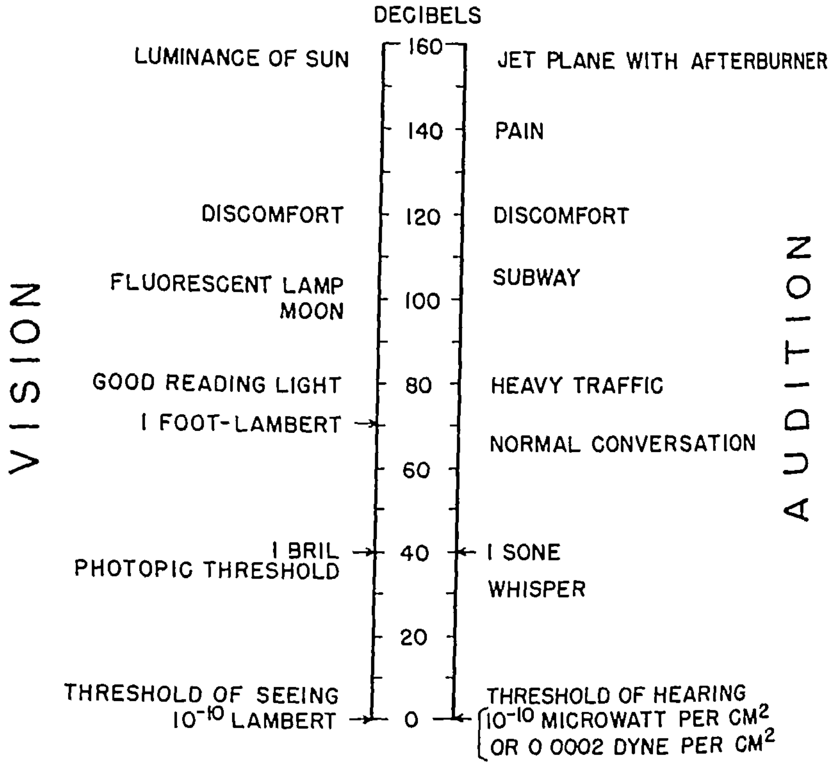

Fig 1 A decibel scale for light and sound showing the approximate levels of luminance and of sound intensity produced by various sources together with a few important threshold levels The points indicated by arrows are exact levels fixed by definition The other levels are approximations only

is hard on the ears, just as looking directly at the sun is hard on the eyes Both are far above the level where discomfort begins, which is at about 110 to 120 db on both scales The comfortable brightness for seeing and the comfortable loudness for listening are both near the middle of these decibel scales, and when stimuli are less than about 40 db we strain to perceive them

These decibel scales demonstrate that the dynamic ranges of vision and audition are enormous The sense organ processes that turn physical energy into nervous energy are such that the output of the sense organ grows with the input over a range of the order of 150 db In this respect, our sense organs are probably superior to any man-made transducers yet devised

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For a 1000-cycle tone, the standard reference signal whose sound pressure level we use as the yardstick to measure loudness level in phons, the rule is roughly the same. From the pooled results obtained in several different laboratories we have determined that the loudness in sones *S* is related to loudness level in phons by the formula

$$\log S = 0.03P - 1.2$$

This formula tells us that in order to change loudness by a factor of two we need to change the stimulus by 10 phons.[9]

The approximate similarity between loudness and brightness is shown in Fig. 2. In both experiments we merely asked observers to assign numbers to the various stimuli (presented in irregular order), and to try to make the numbers proportional to the apparent loudness or the apparent brightness. The brightness experiment was conducted by J. C. Stevens. The fact that the data fall on straight lines in a log-log plot shows that both loudness and brightness are proportional to the stimulus intensity raised to a power.

What we learn from all this is that the loudness heard by a normal ear does not bear a simple one-to-one relation to sound energy, nor to sound pressure, nor to decibels. What we perceive is a sensation resulting from the complex action of the ear and the nervous system, acting as transducers in a manner we do not yet fully understand.

RECRUITMENT

Let us now discuss another similarity between vision and audition. It concerns the problem of recruitment, a subject of great interest to audiologists. In its extreme form, recruitment is a striking phenomenon, because an ear that shows recruitment may be hard-of-hearing for faint tones and yet hear loud tones with the same loudness heard by a normal ear. In other words, as the intensity is increased, loudness grows more rapidly in some ears than in others.

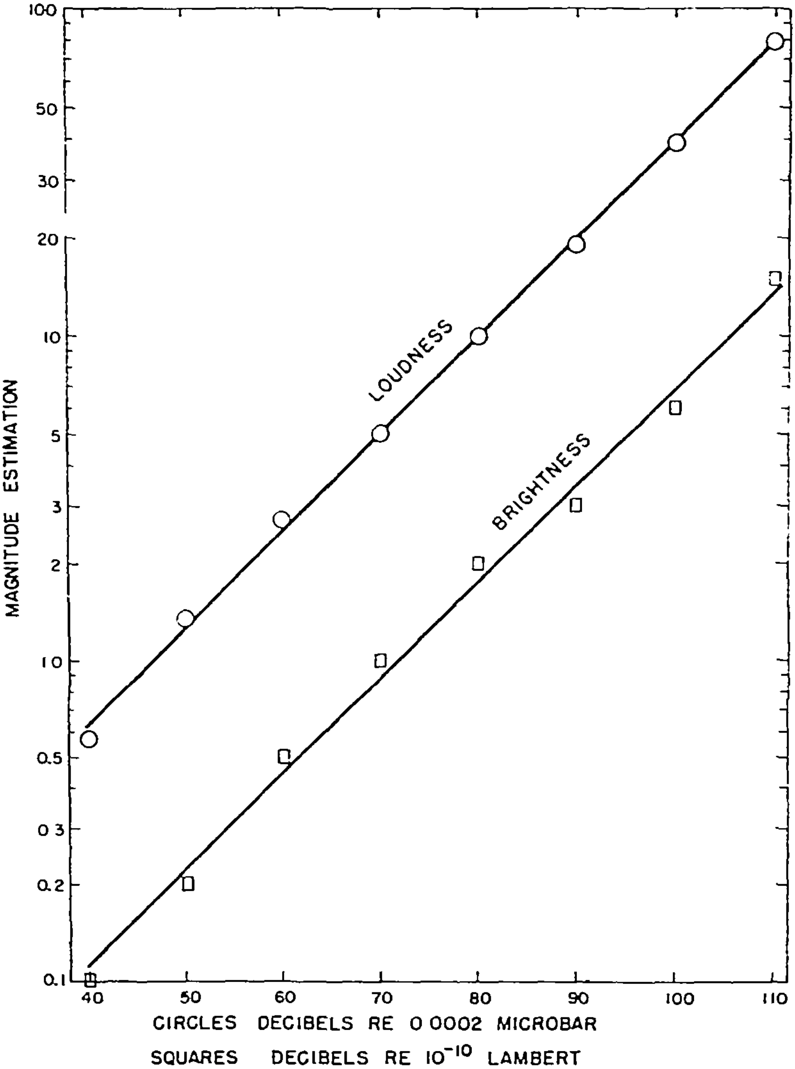

Fig 2 Median magnitude estimations for loudness and brightness For loudness each of 32 observers made two estimates of each level of a 1000-cycle tone For brightness each of 28 dark-adapted observers made two estimates of each level of a white light The target subtended a little less than 5 degrees and was illuminated for about three sec. at each presentation. The two sets of data have been separated vertically by an arbitrary amount. Hence the ordinate scale is relative only

Actually we can distinguish at least four ways in which the rate of growth of loudness with intensity can be altered All four of these are sometimes referred to as recruitment They are as follows

1 *Recruitment as a function of frequency* The loudness of low-frequency tones grows more rapidly than the loudness of high-frequency tones Thus, when a tone of 50 cycles per second is only 30 db above threshold, it may sound as loud as a 1000-cycle tone that is about 50 db above threshold

2 *Recruitment under masking* The presence of a masking noise raises the threshold for a tone, but when the intensity of the tone is raised above the masked threshold, the loudness of the tone grows rapidly When the intensity of the tone is raised sufficiently far above the masked threshold, the tone sounds as loud as it would sound if no masking noise were present

3 *Recruitment under fatigue or adaptation* Exposure to a loud noise may temporarily raise the threshold of the ear by as much as 60 db or more In an ear suffering from such a temporary hearing loss, loudness grows more rapidly with intensity than in an ear that has not been fatigued by a loud sound

4 *Recruitment in pathological ears* There are diseases of the ear that can cause hearing losses for faint tones without greatly impairing the loudness perception of intense tones We know that this kind of recruitment exists, but we still have much to learn about its causes

What concerns us here, however, is not so much the causes of recruitment as the fact that analogous phenomena occur in vision This is an important fact which we should keep in mind when we are tempted to theorize about the mechanisms underlying recruitment The phenomenon is by no means limited to the auditory sense

Each of the four classes of recruitment which we have already discussed has its parallel in vision Let us consider each of them in turn

1 As is true for loudness, brightness varies with intensity

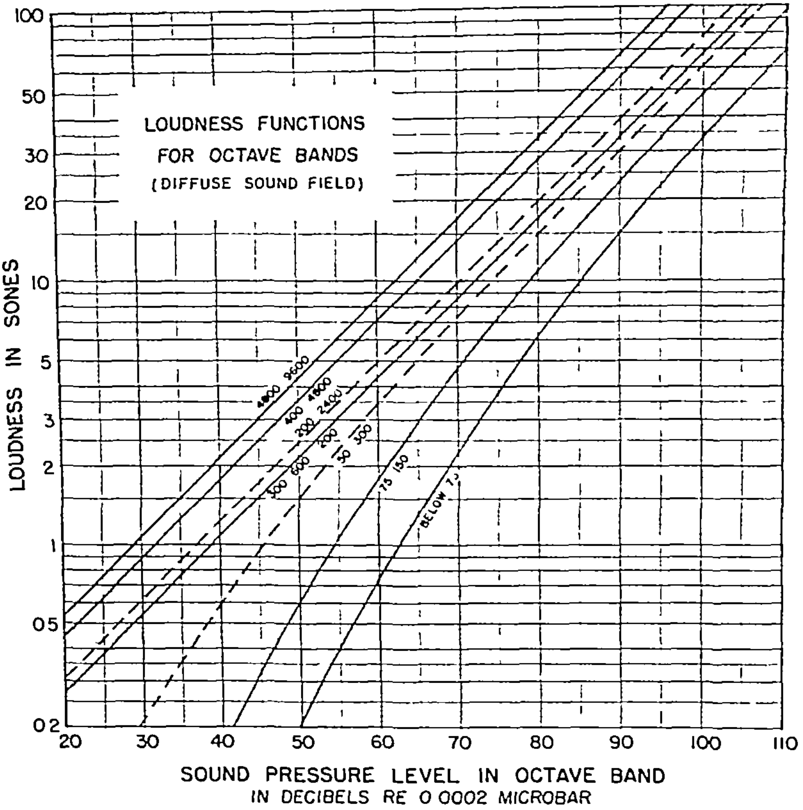

Fig 3 The relation between loudness and sound pressure level for octave bands

more rapidly for some wave lengths than for others Thus a red light appears to grow brighter at a faster rate than does a green light when the intensity is raised above threshold

These basic facts are shown in Figs 3 and 4 Fig 3 shows how the loudness of various octave bands of noise grow with sound pressure level This chart was prepared to facilitate the calculation of the total loudness of a noise on the basis of octave-band measurements[10] The total loudness turns out to be the loudness in sones of the loudest octave band plus 30 per cent of the sum of the loudnesses in all the remaining bands

The rapid growth in the loudness of the low-frequency

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Each of the four classes of recruitment which we have already discussed has its parallel in vision. Let us consider each of them in turn.

1. As is true for loudness, brightness varies with intensity

threshold of a tone, but as the level of the tone is raised its loudness soon reaches the value it would have if the masking noise were not present[2] In Fig 6 we see that a very similar effect takes place in the eye Bright glare patches were placed beside a stimulus target viewed with one eye, and the brightness of the target was matched by a target in the other eye,

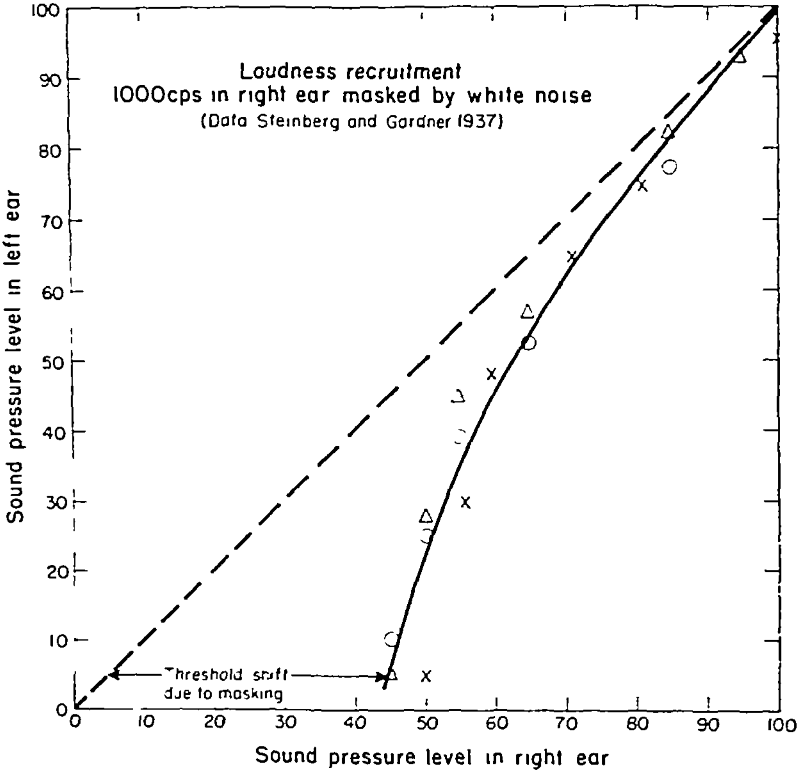


Fig 5 Loudness recruitment under masking

which was not subjected to glare The unfilled points are from an experiment by Diamond[3] The filled points show our attempt to complete the curves by determining the threshold shift under the same stimulus conditions

3 We have also found that in the eye that has been exposed to a strong light brightness grows more rapidly with intensity bands in Fig 3 has a rough parallel in the rapid growth of the luminance of red light (650 mμ) shown in Fig 4 *Luminance,* when measured in decibels, is analogous to our concept of *loudness level,* and is proportional to the logarithm of the subjective brightness The data in Fig 4 are from estimates made by Weaver[11]

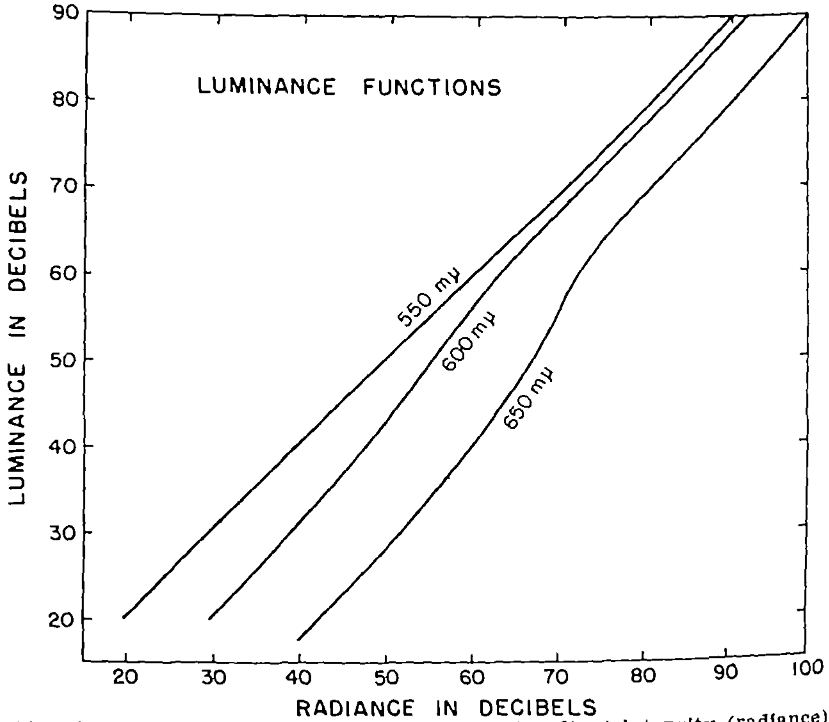


Fig 4 The relation between luminance and radiant intensity (radiance) for three different wave lengths of light ranging roughly from yellow to red

2 Masking in hearing has its analogue in what is called *glare* in vision In the presence of a source of glare, the absolute threshold of the eye is raised, but when the stimulus is made more intense than the glare the apparent brightness of the stimulus grows to the value it would have even though the glare were not present Thus *masking* recruitment occurs in both vision and audition

Recruitment curves under masking and glare are shown in Figs 5 and 6 As shown in Fig 5, masking raises the shown in Fig 7 was obtained by exposing one ear to a wide band of noise for 32 minutes at a sound pressure level of 130 db[2] Loudness balances were then made between the exposed and the normal ear at five frequencies between 1000 and 1700 c p s The points in Fig 7 represent the averages for the five frequencies We see that, although the threshold was

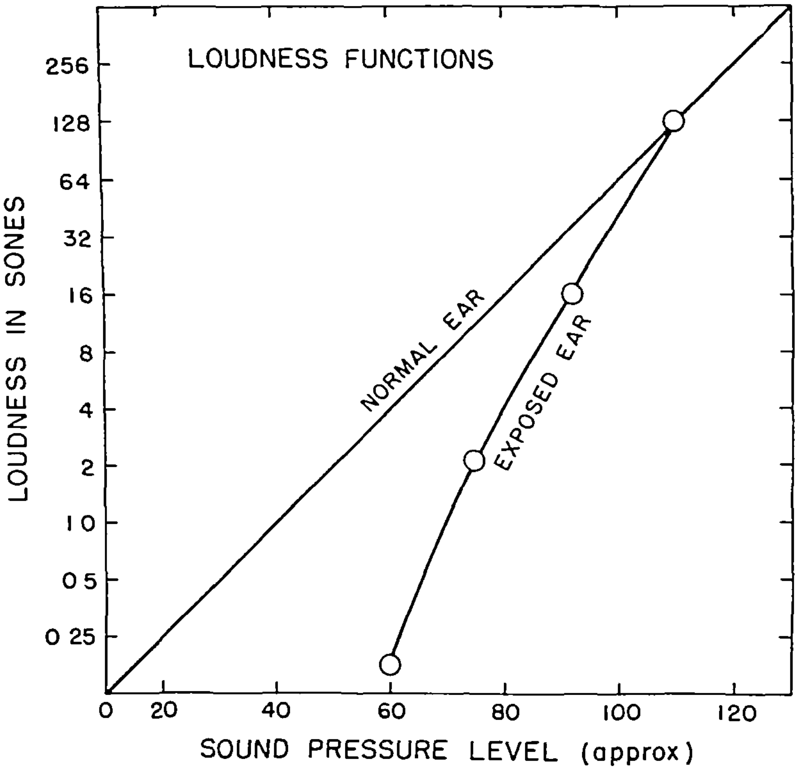


Fig 7 An example of a temporary hearing loss produced by exposure to an intense noise The exposed ear shows loudness recruitment

raised by the noise exposure, the loudness heard by the exposed ear was essentially normal for tones at an SPL of about 110 db

The effects of exposing the eye to bright light are shown in Fig 8 These data show that over the low luminance levels the light-adapted eye shows recruitment, *i e*, the curves are than it does in the eye that is dark-adapted Exposure to strong light raises the absolute threshold of the eye in much the same way that exposure to intense sound raises the threshold of the ear There are many important differences here, but in both cases the perception of intense stimuli remains more nearly normal than the change in threshold would lead us to expect In other words, brightness recruitment occurs in the light-adapted eye, just as loudness recruitment occurs in the ear that has been temporarily fatigued

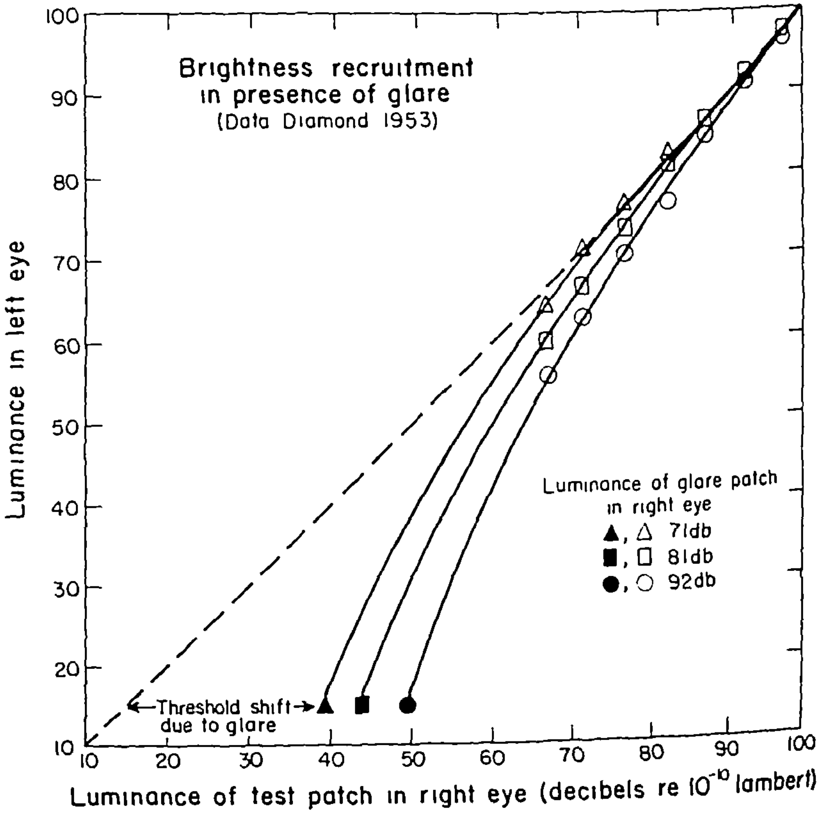
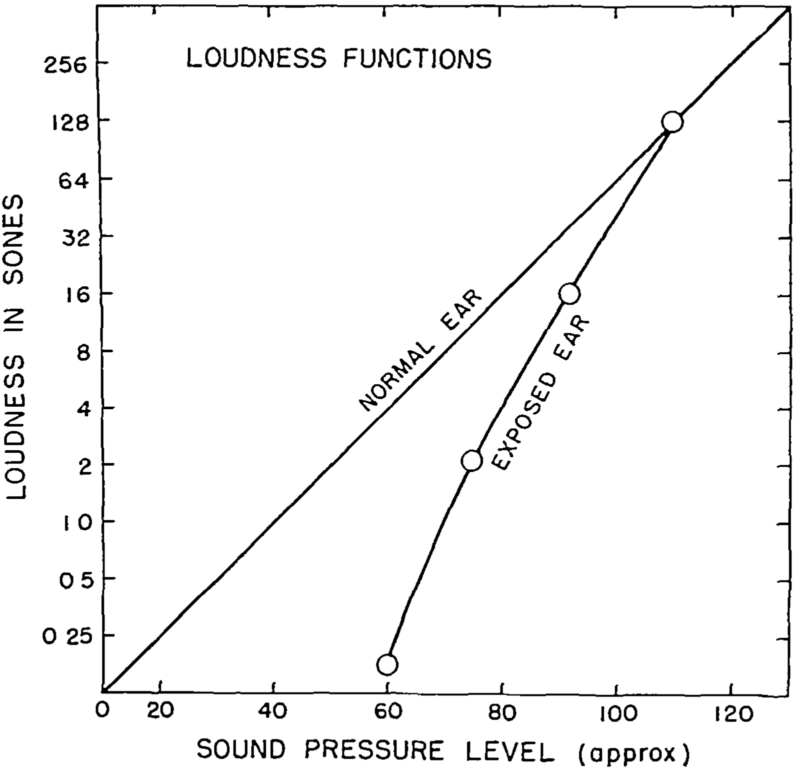


Fig 6 Brightness recruitment under glare

These relations are shown in Figs 7 and 8 Actually the effects of exposure to intense sound are quite variable, and so are the resulting recruitment curves The particular curve shown in Fig 7 was obtained by exposing one ear to a wide band of noise for 32 minutes at a sound pressure level of 130 db[2] Loudness balances were then made between the exposed and the normal ear at five frequencies between 1000 and 1700 c p s The points in Fig 7 represent the averages for the five frequencies We see that, although the threshold was



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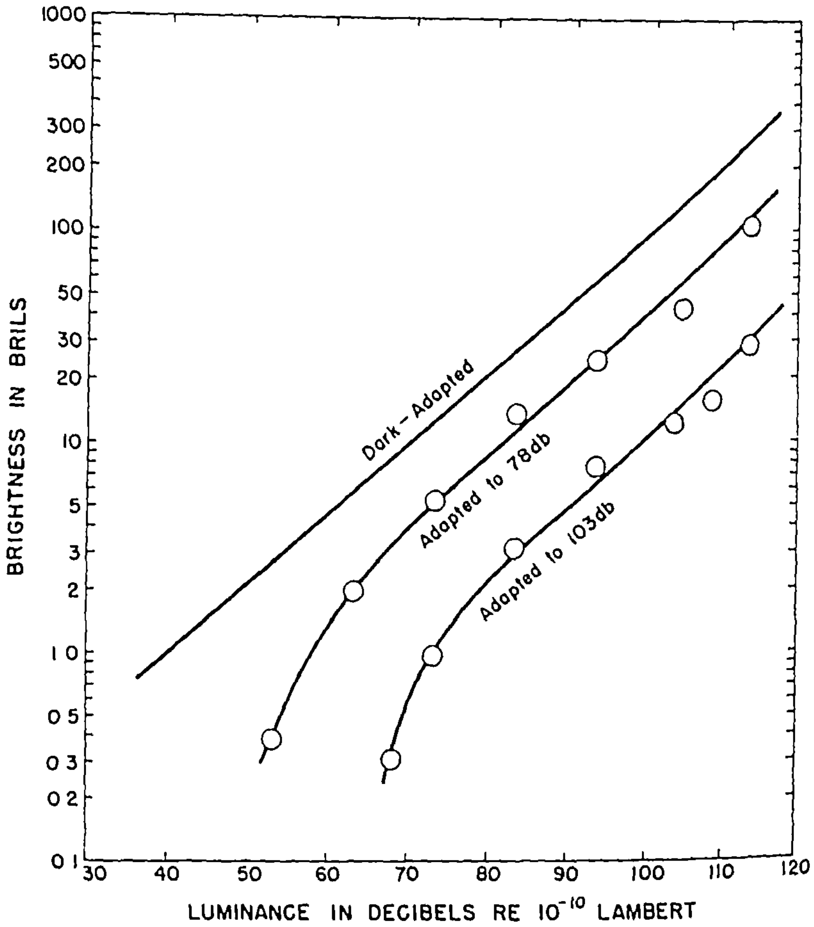


Fig 8 Showing how light adaptation leads to brightness recruitment at low levels of luminance

steep at the low end On the other hand, there is an important difference to be noted In the eye the recruitment is not complete In other words, after our eyes are adapted to a bright light, all lights look dimmer than they would if we were dark adapted, but the effect on lights near threshold is relatively greater than the effect on the higher levels

It should be mentioned that the positions of the curves through the points in Fig 8 were determined in an experiment[1] involving brightness balances between the two eyes, with one eye dark adapted and the other light adapted The points themselves were obtained by J C Stevens, who asked groups of 18 light-adapted observers to estimate the apparent brightness of various stimuli

4 Certain pathological conditions in the eye can also raise the absolute threshold without causing a correspondingly large change in the apparent brightness of intense lights I have recently had the opportunity of examining a case of what is called congenital stationary night-blindness The patient was a young man who apparently saw quite normally under high illumination (except for a slight myopia) but who saw nothing when the luminance was below about 40 db He has a brother and a sister who have similar deficiencies So far as I know, brightness perception in these cases has not been explored as thoroughly as loudness perception in ears that show auditory recruitment, but the fact that visual recruitment seems to exist in certain abnormal eyes is interesting evidence of a further functional similarity between the eye and the ear

In these remarks I have stressed some of the functional similarities between vision and audition It would be equally possible, of course, to stress the differences between these two remarkable sense organs, for there are indeed important differences Even where their behavior is similar, the underlying mechanisms may of course be quite different Not all the problems faced by audiology are similar to the problems that arise in the visual sciences, but there are enough parallels between the general laws of vision and those of hearing to make it highly profitable for us to study the eye in order to learn more about the ear and vice versa

Let us consider one final matter, concerning another type of loudness growth—a phenomenon that could be regarded as a form of recruitment, but one that seems to have no parallel in vision dependence of loudness on the band width of a sound From recent studies of this phenomenon there emerges the important concept of a critical band width

Figs 9 and 10 show examples of data from a study by Zwicker, Flottorp and Stevens[12] In these experiments the listener made a loudness balance between a comparison sound and either a complex of four pure tones (all at a constant

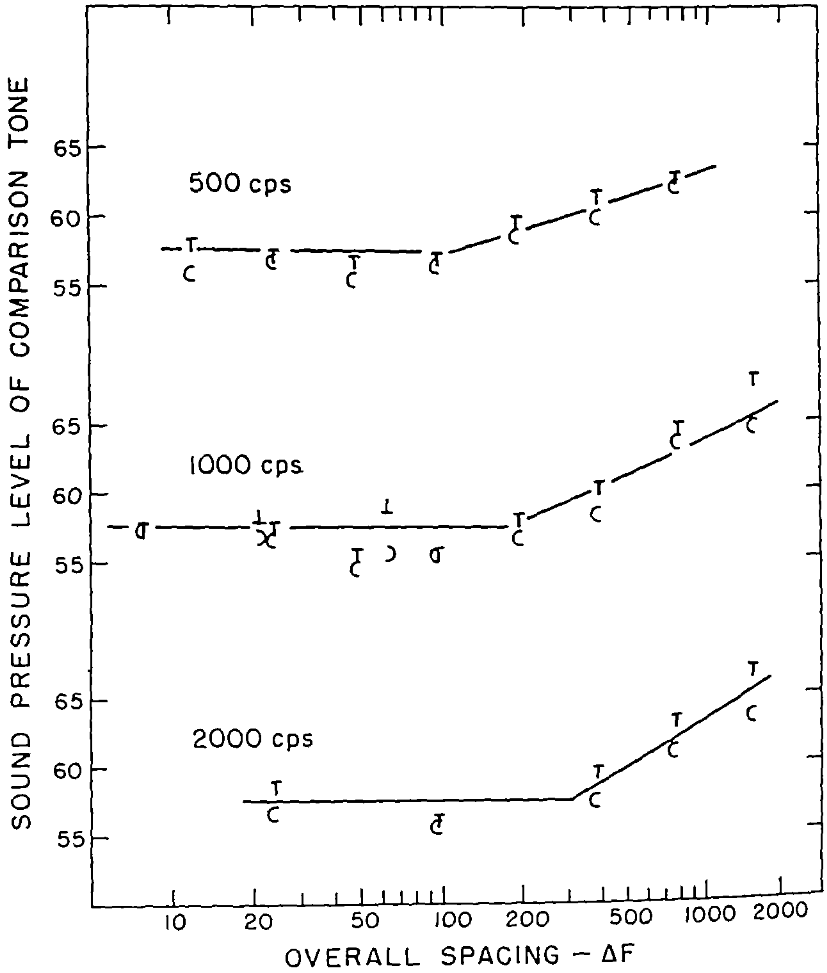


Fig 9 Showing how loudness depends on the overall spacing ΔF of a four-tone complex. The spacing of the tones was uniform about the center frequency indicated on each curve Each point is based on loudness balances by 16 to 22 listeners The symbol T means that the single comparison tone was adjusted C means that the complex was adjusted The lines through the data have a break at the frequencies determined by other critical-band determinations

level) or a band of noise In Fig 9 we see that, as the spacing between the tones is increased, the loudness of the complex remains essentially constant until the over all spacing ΔF reaches a critical value Beyond that point the loudness grows as the spacing is increased In other words, there is a kind of recruitment The critical value of ΔF depends on the frequency region in which the tones lie

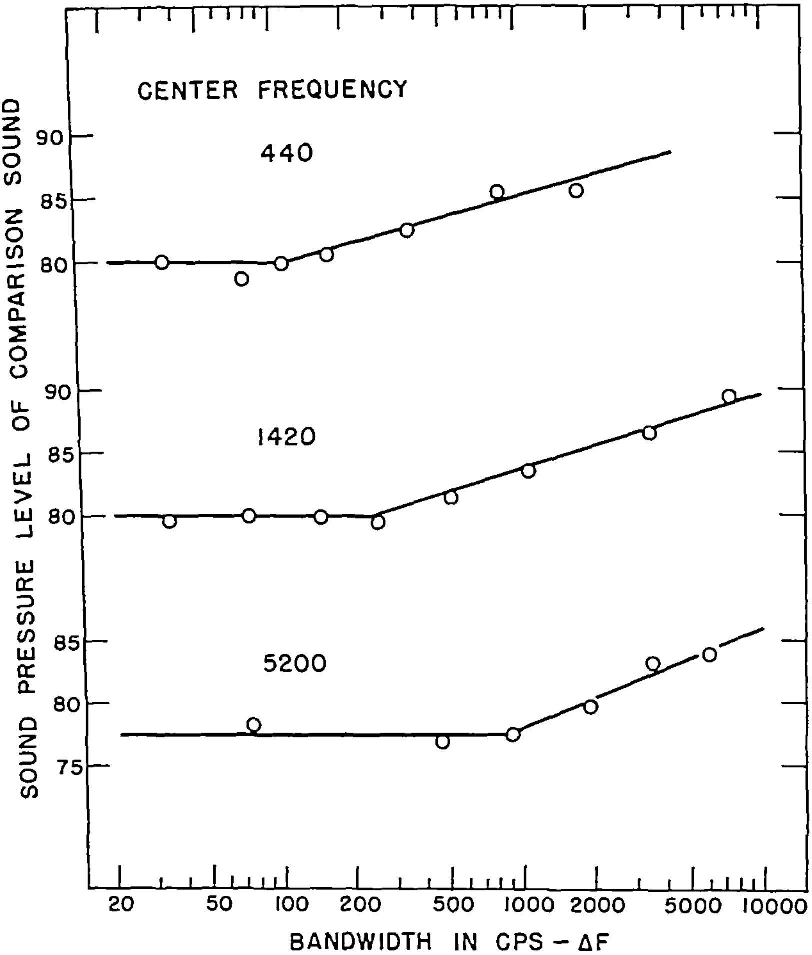
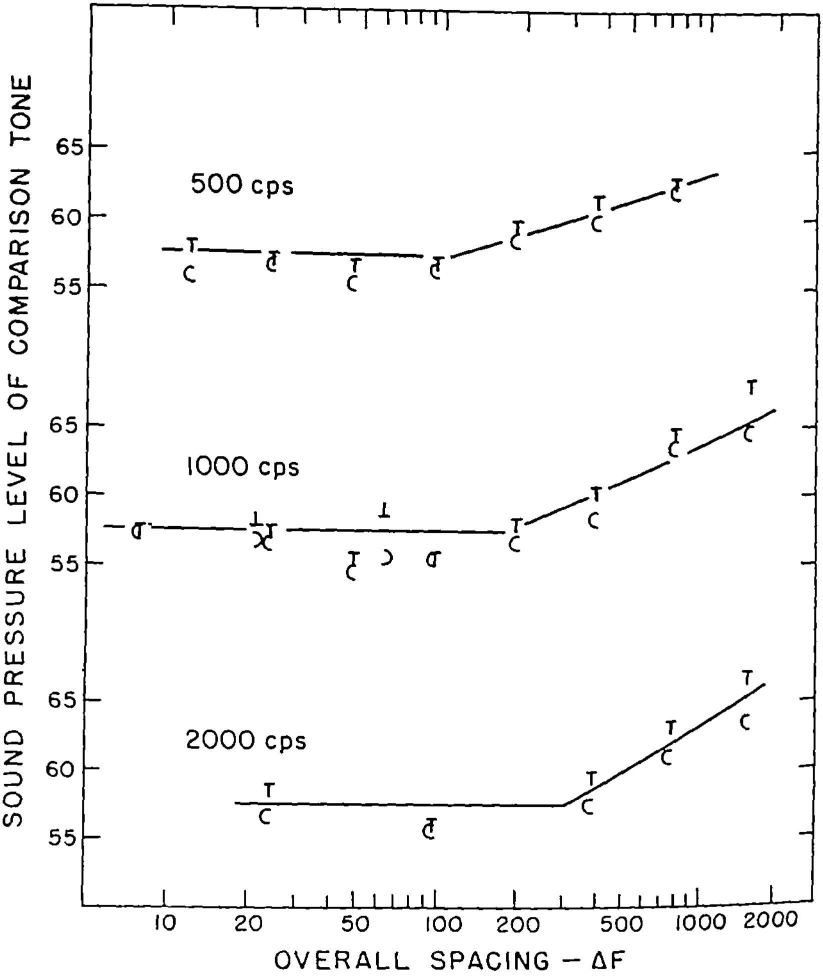


Fig 10 Showing how loudness depends on the band width ΔF of a noise of constant sound pressure level The lines through the data have a break at the frequencies determined by other critical-band determinations

In Fig 10 we observe a similar effect when we increase the width of a band of noise whose over all sound pressure level is held constant Beyond a critical point the loudness increases with band width, but as long as the energy lies within a critical band all that seems to matter for the determination of loudness is the sound pressure level of the noise In fitting the lines to the data in Figs 9 and 10 we placed the break between the horizontal and the rising segment at the points



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AN ATTEMPTED SYNTHESIS OF PSYCHO-ACOUSTIC TEST DATA IN THE AUDIOLOGICAL CLINIC

J DONALD HARRIS,

U S N Medical Research Laboratory,

New London, Conn

More than a dozen separate tests, based upon as many different principles, have been proposed in recent years to assist in distinguishing "conductive" and "perceptive" deafness Many of these tests, even the classic Weber and Rinné examinations, do succeed well in making this first distinction, and some, such as careful BC audiometry, can often give a quite precise idea of the relative components in mixed deafness

One notes that the terms "conductive" and "perceptive," in past decades thought useful and clearcut, are today eroding rapidly A variety of causes and sites of "conductive" lesion render that term a catch-all with less precision than now required Mygind and others even speak of "conductive" lesions within the cochlea, here the original division has broken down completely On the other side, it is now clear that the category of "perceptive" deafness has even less explicit meaning It is relatively useless to lump all disorders of the auditory mechanism from perilymph to cerebrum under one compendium phrase, if one can be more specific

It is fair to say that one of the advances which has assisted otologists to be more specific has been the introduction into the clinic of a great deal of psycho-acoustic thought by the otologists and by supporting persons There is implicit here a whole new concept in otological diagnosis, namely, that since a particular physical disorder of pathology in certain dictated by measurements made in three other types of experiments In other words, four different techniques have converged on the determination of this critical band width

The critical band width thus measured turns out to be about 2 5 times as large as the critical band width originally proposed by Fletcher,[4] which was based on a different kind of experiment, nevertheless, in their dependence on frequency both Fletcher's band and this new band follow much the same course The width of the new critical band is about 90 c p s at the low frequency end of the spectrum Near 1000 c p s the widths is about 170 c p s , and near 10,000 c p s it is about 2400 c p s

Not only does this critical band width emerge in different kinds of experiments, but it also seems to be closely related to other important auditory functions For example, each critical band occupies about the same width on the basilar membrane Each band contains about the same number of just noticeable differences in pitch, and each contains roughly the same number of mels (units of subjective pitch) We have reason to believe, therefore, that this critical band width may come to hold an important place in auditory theory

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Loudness-Increments Sensitivity
Sensitivity for Loudness by Constants
Pitch-Modulation Sensitivity
Pitch-Memory Sensitivity
Perstimulatory Adaptation
Post-Stimulatory Adaptation and Fatigue
Temporal Integration
Pure Tone Distortion Threshold
Masking of Speech and Pure Tones
Intelligibility of Speeded and Reverberant Speech

That this list is by no means complete is indicated by the fact that each of these tests has a bibliography of from several to dozens of items In one recent review of recruitment, for example, over a dozen tests of recruitment and/or closely allied topics were listed For another example, the field of loudness discrimination is burgeoning, and new tests not listed above are appearing all the time

A number of these tests have been worked up for entirely non-clinical purposes, and their present audiological relevance has arisen mainly by chance—witness the work of Bekésy, Hood and others Some writers have created audiological tests on the basis of some good guess as to the nature of the disorders and the capacities of the defective ear—Luscher, Langenbeck, Huizing, Hood again, Miskolczy-Fodor, and others What happens is that someone suddenly has an idea that pitch discrimination, reverberant speech, or auditory masking, may assist in otological diagnosis, and a number of patients (it is the rule to use far too few for any solid reliability) are given the new test, with the result that the original author is quite enthusiastic about its nosological meaning

Following this, another laboratory or clinic, changing experimental conditions freely, gives what is said to be the same test and finds conflicting or ambiguous results This exact sequence has happened with tests of residual auditory fatigue, with masking, with intensity discrimination, with temporal integration, and with perstimulatory adaptation, to name several recent examples At the present time, all workers are convinced that the principle is sound, that such patients can be shown to cause atypical behavior on a certain psycho-acoustic test, that test may be useful in throwing light on the diagnosis in another patient whose purely physical examination yields ambiguous concepts as to the locus or etiology of the dysfunction

Otologists have been impelled to seek for such inferential light in diagnosis of "perceptive" disorders because for the most part, these tissues in the auditory mechanism are, and must remain, inaccessible to the otoscope, and even to the exploratory surgery of the tympanum, in which such giant strides are currently being taken, however this may be in the future, it now seems possible with psycho-acoustic assistance to go beyond the rather coarse conductive-perceptive dichotomy and begin to break down the latter category into at least three subdivisions, neural, end-organ, and cochlear (non-end-organ) The neural category can of course be broken down further in some patients, and there is even the hope that in the future an attack can be made on the very indefinite category "cochlear (non-end-organ)"

Having thus placed psycho-acoustic thinking in perspective as a part of the armamentarium of the otologist, it remains to consider what test or tests could, or even should, be available in the complete clinic I should like to draw your attention to *1* a brief discussion of how some of the present psycho-acoustic tests have come to be suggested, *2* turn to one rational line of reasoning as to how a complete and mutually exclusive battery of such tests might be constructed, *3* how a "profile" of test results may correlate higher with diagnosis than results from any one or two tests

It will be instructive first to list a few of the psycho-acoustic tests or criteria which have been proposed for the clinic

AC-BC Audiogram, Level and Shape
AC-BC Differential
Threshold Uncertainty Interval
Shape of Speech Intelligibility Function
Loudness Balancing, and Shape of Recruitment Curve
Loudness-Modulation Sensitivity

Loudness-Increments Sensitivity
Sensitivity for Loudness by Constants
Pitch-Modulation Sensitivity
Pitch-Memory Sensitivity
Perstimulatory Adaptation
Post-Stimulatory Adaptation and Fatigue
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The difficulty with these multi-various test possibilities is that they are not mutually exclusive, or in other terms, they are not factorially pure auditory traits A pure auditory trait is assumed to have a direct relation to the way the ear transduces and transforms the acoustic stimulus into cochleo-neural events A particular psycho-acoustic test, on the contrary, may be far from pure, partaking of so many primary auditory abilities that its results become ambiguous This means that a patient's atypically poor performance on this test cannot throw any light on the condition of specific tissues or processes in the auditory mechanism

As a result of studies at this laboratory* we now know, for example, that pitch discrimination, long thought to be a primary auditory ability, is actually broken down into two factors, pitch-memory and pitch-modulation A normal ear may be very good on one of these traits but only average on the other A defective ear on the same head may show a different pattern For another example, the detection of speech in noise is found *not* to be related to the detection of a sine wave, or bands of noise, or clicks, or Gaussian pulses, but is factorially complex with a large specific component of its own with alliance to factors of pitch and temporal patterns For a third example, we suspect speeded-up speech to be factorially fairly pure, by analogy, in the field of intelligence testing, to the primary mental ability of verbal facility

Only when a test is factorially pure can there be a chance of its representing fairly elementary operations of the auditory mechanism, so that if an ear performs badly on that test, the source of trouble in the auditory mechanism can be pinpointed A factorially complex test will almost hopelessly becloud the clinical issues We have already seen this happen for loudness discrimination, as I shall amplify later

I feel it is now possible to take a completely rational approach to the problem of audiological tests, using the technique of factor analysis as mentioned Our work using this approach in pitch discrimination, loudness discrimination, contact detection, and speech reception has been summarized * We can now suggest "tag tests" for two pitch factors, three loudness factors, and two or more distorted speech factors

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*MRL Report No 57-4

As a paradigm, let us examine the matter of psycho-acoustic tests for susceptibility to acoustic trauma Many industrial physicians and audiologists have proposed a brief exposure to moderate sounds, and a single threshold-shift index assigned to each man, but these proposed tests have used exposures ranging from 0 4 sec to 10 min frequencies over a broad range including white noise and clicks, and a wide variety of other dissimilarities exists Should one give all these tests? The technique of factor analysis provides a means to reduce them to the fewest number which will sample the whole field of temporary threshold shift Large groups of subjects would serve for the following program

a Outlining the area with a dozen or more specific test ideas One would include among other things tests of aural overload, latent damage, short-duration adaptations, etc

b Tape-recording these preliminary tests with appropriate psycho-acoustic equipment and psycho-physical techniques acceptable by today's standards

c Trying them out for reliability, and standardizing them on pilot groups

d Tape-recording a final battery of tests and presenting to at least 200 subjects with normal ears

e Inter-correlating and factor analyzing

f Interpreting the data in terms of primary auditory abilities

The smallest number of tests which would explain variance among subjects would then be cast into a predictive battery and administered to men destined for high noise areas

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*MRL Report No 57-4

Such an approach, with tapes widely distributed in several countries, would bring order into a confused field and bring final predictive success much closer to reality

Exactly the same sort of statistics-plus-psycho-acoustics is suggested for the otological clinic, except that the final winnowing of standardized pure tests in any area, such as loudness discrimination, would be further used to explore the diagnostic significance of each of the several primary abilities within the broad area of loudness discrimination

It may be well to explain this last point here Luscher and Zwislocki first succeeded in using a measure of loudness discrimination as a clinical index of recruitment, and subsequent data by Neuberger and others from that laboratory have convinced us that, in general, the otological conditions associated with recruitment are also associated with improved sensitivity for amplitude-modulation On the other hand one recalls Denes and Naunton's conclusion, exactly opposite from Luscher's, that near threshold the recruiting ear shows a relative improvement in loudness sensitivity Note, however, that Denes and Naunton used a "constants" method, with an interval of silence between two tones to be judged, it should now be clear why we feel that the techniques of loudness sensitivity by the "constants" method and the "amplitude-modulation" method *both* are applicable to the defective ear, and can both be used to assist in diagnosis Rather heavy criticisms of each method have been made by the other school, on the basis that "amplitude-modulation" produced side-bands to blur the "quality" of the tone or that the "constants" method yields an incongruously poor sensitivity at higher intensities, but it seems that such criticisms are beside the point, furthermore, it is not at all necessary to survey the several inconclusive reports and the several apparently contradictory reports, throw one's hands up and simply await the appearance of further inconclusive and inconsistent reports

The difference in results between the "constants" and the "modulation" tests goes far beyond the elementary notion that the exact value of a DL depends upon the techniques used to measure it—here we are not dealing with the same auditory trait In "amplitude-modulation" the ability is rendered more acute by whatever otological conditions cause recruitment, and this improvement exists at about equal strength over the whole range of sensation level On the other hand, in "constants" the ability is rendered more acute but *only in the region of rapid recruitment* A particular type of pathology may affect one trait in one way and the other in a quite different way

With this thought in mind we are better able to assess the several reports which have appeared since the original validating papers These reports are mutually informative, not contradictory

I have said perhaps enough to point out how we expect to generate newer and more meaningful ("purer") tests for auditory traits with continued effort Particularly, we feel that the areas of speech, of temporal patterning and rhythms, of masking and contact detection, of auditory fatigue and adaptation, and the area of inter-factor relationships must be explored

I now direct your attention to the third point, that in a particularly difficult diagnostic situation one may look at not only the results of tests one by one, but also at the interrelations among the sets of results It is the pattern, or profile, that may well be the really important clue For example, presbycusis is often characterized by lowered BC, a certain slope of audiogram, absence of recruitment, distortion of temporal integration, and lack of resistance to speeded speech If one looked at only one or two of these tests an uncertainty might exist, but the total picture becomes clearer when the test profile is considered For another example, we have published data showing that improved loudness discrimination need *not* be paid for with a deteriorated pitch discrimination, but that this is *always* true with acoustic trauma among subjects would then be cast into a predictive battery and administered to men destined for high noise areas

Such an approach, with tapes widely distributed in several countries, would bring order into a confused field and bring final predictive success much closer to reality

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The difference in results between the "constants" and the

TRIPLET TESTING AND TRAINING—AN APPROACH TO BAND DISCRIMINATION AND ITS MONAURAL OR BINAURAL SUMMATION

HENK C HUIZING and M TASELAAR,
University of Groningen,
The Netherlands

Recently the principle of what may be called qualitative speech audiometry has excited the interest of some investigators Kruisinga[1] studied the phenomena of phoneme confusion in cases of abrupt deafness, and he also investigated, in various types of hearing impairment, the change in intelligibility of the spoken voice as compared to that for the whispered voice

Guberina[2] examined the residual articulative function of impaired ears in discrete octave bands by using adequately chosen logatoms as test material

The great difference in change of the articulation curve for spoken voice as compared with that for whisper in different types of hearing impairment focused our attention to the significance of the test material in a qualitative sense This gave us the idea of measuring band articulation, while retaining intelligible speech as test material The great redundancy, which characterizes normal speech under favorable conditions makes it possible to use narrow band speech which is still intelligible

By means of suitable filters we are able to narrow the band width more and more until we approach the threshold of intelligibility for the normal ear To cover the whole tone scale by subsequent frequency bands, three different samples of speech are necessary, *i e* a low, a medium and a high quality of speech. Fig 1 shows the width of each of the three frequency bands equally weighted as to intelligibility for the Dutch language The filter characteristics are given in Fig 2

This split-up of the tone scale in three equivalent parts, with conserved intelligibility in each presents the possibility

We have a patient with advanced otosclerosis who exhibits a breakdown in "intensity-modulation" at weak levels, but whose loudness by "constants" remains quite good We have a patient with a pure conductive loss by BC, perstimulatory adaptation, and a half-dozen other signs, but who exhibits straight-line recruitment, disturbance of temporal integration, and diminished intensity-modulation We have a patient with a sudden unilateral loss above 500 c p s caused probably by a vascular spasm, with no AC-BC differential, extreme disturbance of temporal integration but with delayed and slight straight-line recruitment We have several patients with quick and complete recruitment, disturbance of temporal integration, no AC-BC differential, and history of acoustic trauma, but some do and some do not show unusual perstimulatory adaptation We have a patient with mixed deafness which would be considered purely conductive except that extremely distorted temporal integration reveals a minor cochlear lesion We have a patient with high tone cochlear deafness probably familial, with quick straight-line recruitment which indicates that cochlear lesions in addition to acoustic trauma and Menière's disease can distort temporal integration

It is no trouble to explore the protocols of patients in the literature from the practices of Palva, Bocca, Fournier, and also dozens of otologists in this country, who are accustomed to giving several psycho-acoustic tests where indicated or where possible, to find similar instances

Such of our data as seem internally self-contradictory we regard as among our potentially most powerful results They are at least not due to scanty sampling, since we are able to schedule both our civilian and our military patients for six to ten hours or more if needed We regard as in the pioneer stage only, the concepts of factorially pure auditory abilities and tests for them, and of the correlation between pathology in any tissue and a concomitant set of results on a multifactor test battery Our successes have been limited and have come slowly, but fortunately they have appeared at a rate just sufficient not to extinguish our conditioned drive bility is given by that part of the tone scale in which the threshold loss is smallest Depending upon the shape of the threshold audiogram the cerebral patterns of the patient may be low tuned, medium tuned or high tuned It appears that the shift in energy balance between the various frequency bands is closely related to the category of listeners to which the patient belongs

4 Triplet speech audiometry provides useful information

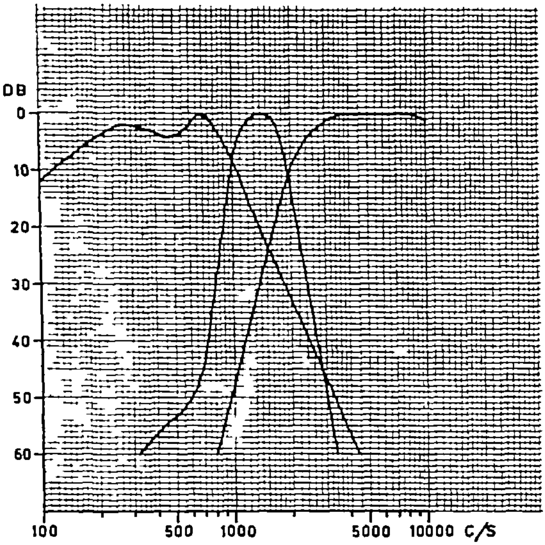

Fig 2 Filter characteristics used to realize a triple speech sample in equally weighted frequency bands (low medium and high)

regarding the fitting of a hearing aid on an analytic basis The analysis may tell us whether it is advisable to try to restore more or less the normal energy relations along the whole tone scale, or that preferably we should confine ourselves to a more or less selective amplification of that part of the tone scale in which the patient's discrimination skill has been kept up

5 In connection with band discrimination analysis we

of obtaining insight into a patient's partial discrimination ability We need only to determine his sentence intelligibility or his spondee articulation score at his most comfortable level

The application of this triplet audiometry on hard of hearing individuals leads to the following conclusions

1 Triplet audiometry provides more information about the residual discrimination ability of a patient, especially as to its distribution along the tone scale

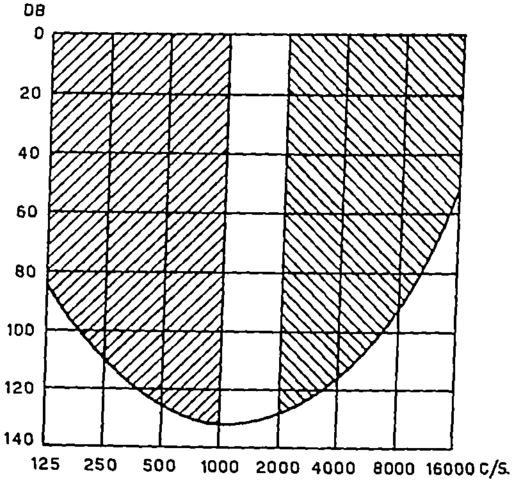

Fig 1 Triplet frequency bands equally weighted as to intelligibility for the Dutch language

2 Depending upon the type and the duration of his hearing impairment, a patient's discrimination ability may be based upon a normal distribution of discriminative capacity along the whole tone scale, or it may be that his residual discriminative power is mainly concentrated in a rather narrow band of frequencies The latter may be the case despite the fact that his threshold audiogram still covers the whole tone scale

3 In cases of long standing deafness with a non-uniform threshold loss in general, the main contribution to intelligi-

EFFECTS OF AMBIENT NOISE ON SPEAKER INTELLIGIBILITY OF WORDS AND PHRASES *

JOHN J DREHER,
and
JOHN J O'NEILL,
The Ohio State University Research Foundation,
Columbus, O

I INTRODUCTION

Some years ago it was noticed that a speaker with normal hearing would unconsciously raise the level of his voice to compensate for the level of noise in which he was speaking This phenomenon was incorporated in the development of the "Lombard," or "voice-reflex" test, which was used to detect malingering in the testing of hearing It would be supposed that as the ambient level of noise for a speaker became greater there would be some changes in his intelligibility Hanley and Steer[2] found that untrained speakers, in the presence of noise, tended to reduce their rate of speaking, prolong syllables, and speak with greater intensity as the noise increased Subsequently, Pickett and Kryter[3] concluded that as a speaker increased his vocal intensity from normal level to a shout, his intelligibility decreased at the higher levels It is noted here, however, that their increases in vocal intensity were accomplished by raising the voice in quiet surroundings, technique that may result in speech with characteristics different from those produced by a speaker actually fighting noise It was not unreasonable to suppose that speech produced in noisy surroundings might actually incorporate some compensatory factors in it, and that within a certain limited range it might be more effective for a listener under poor reception conditions

If it could be shown that some of these changes actually

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*This study was done under Contract No AF 19(604)-1577 with Operational Applications Laboratory Bolling AFB Washington 25 D C (Report AFCRC TN 57-52 ASTIA Document No AD-110-068) direct attention to two-channel amplification To the credit of some data in the literature,[3] and also on account of our own recent experiments, it may be expected that in certain cases of hearing impairment the intelligibility may be markedly improved when the amplified speech is given through two separated selective bands in binaural stimulation For this purpose the distribution of discrimination skill along the tone scale must be known for each individual ear

A double channel system involves a greater flexibility in adjustment of the relative amplification of each frequency band, as well as to the choice of the band for each separate ear It says that a dual set of hearing aids may give a better opportunity of controlling "power" against "discrimination" It is rather this power discrimination relationship which is frequently disturbed due to non-uniform hearing loss, and often is hard to rectify by a single circuit

If in the near future we succeed in introducing the binaural aid, the triplet band data of each ear separately will give us useful information for obtaining an optimum improvement

6 In young children with retarded speech development the triplet discrimination test lends itself principally to the detection of high tone or medium tone deafness (sloping or basin shaped audiograms)

7 Finally this test may tell us whether it is advisable to start an auditory training program in connection with the use of a hearing aid, and if so, what kind of program should be preferable In this connection it should be emphasized that the triplet system lends itself to selective training in each of the three bands mentioned

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speaker's voice was provided by the headset, his monitoring being done only by internal sidetone

Stimulus materials consisted of five sets of spondee words and five air traffic control sentences at each of five recording levels for each of 15 speakers All words and sentences were different for each speaker at each level, that is, he never had the same material to read more than once during his entire recording stint The purpose of this was to prevent any accommodation to the phraseology itself Thus, each speaker read, in all, 25 spondees and 25 sentences His initial recording was made by wearing a dead headset, and his relatively low resultant voice level (65 db , C scale, one meter distant) served as the base level for the other four recording conditions He then recorded, in order, stimulus materials with 70, 80, 90, and 100 db of noise at the entrance to the ear canal To prevent accommodation to the masking level the noise was on in the headset only during actual production of the speech, the appearance of the noise serving as a cue for the speaker to record As soon as the test item was read, the noise was turned off for a given length of time to allow for listeners' written response Three seconds were allowed after each test spondee, eight seconds after each test sentence A push button operated by the experimenter controlled the noise in the speaker's headset

The order of the test material was rotated in such a manner that listeners for each of the recorded conditions heard all test words and sentences, since the final test tapes were arranged to present *1* all speakers' recordings in quiet, *2* all speakers' recordings in 70 db of noise, and so on, five tapes in all

After this collation of materials according to levels, all tapes were re-recorded through a General Electric BA-5A limiting circuit It is pointed out here that peak clip limiting was not employed The operation of this particular instrument is of broadcast quality, set for an attack of 100 microseconds and 0 6 second for 90 per cent recovery The purpose of such limiting was two-fold first, to remove the effects of increased vocal intensity from the experimental situation, act to increase intelligibility, we might anticipate a device that would exploit this fact For instance, a certain amount of masking might be introduced into the speaker's ears by means of a pre-calibrated device attached to his headset The listener, who would not be exposed to this noise, would, however, hear the improved output at his end of the link, and the importance of such a device would be obvious in air traffic control and other military voice communication applications

Inasmuch as automatic volume control is an integral part of modern transmission equipment, the accompanying increase in vocal intensity noted in the "voice reflex" reaction cannot properly be considered as one of the factors legitimate to test Consequently, the loudness (intensity) changes in the voice were compensated for in the construction of the test, a realistic structure in view of the eventual application of voice through a limited system

II EXPERIMENTAL DETAILS

A General Plan—The Lombard reaction, while a general one, varies in magnitude as do other voice measures with individuals, therefore, the plan of the study was to get the reaction of several speakers under several levels of masking at the ear, comparing intelligibility of the speech so produced against a constant background of masking noise with a large number of listeners To avoid attempts on the speakers' parts to control their vocal level, none were informed of the voice reflex phenomenon

B Speakers and Stimulus Materials—Fifteen university students, three male and twelve female, served as speakers All were of general American dialect and inexperienced with voice recording methods

Recordings were made with an Altec 21-C condenser microphone positioned along the speaker's cheek with the button behind the corner of the mouth, out of the breath stream During recording each speaker wore a pair of PDR-8 headphones These headphones fed the taped output of a Grason-Stadler White Noise Generator (Model 455-B) from an Ekotape recorder to the ears of the speaker No feedback of the speaker, and the playback level measured 70 db (C scale) at a point ten feet in front and on the axis of the loud-speaker. Each listening session lasted 30 minutes, with each group of 40 evaluating the speech produced under one of the five masking conditions.

E. Analysis of Data—Intelligibility scores were computed for words and sentences. The latter were scored by percentage of key words correct, the former on percentage correctly identified. Physical measurements of intensity and duration of the original, noise-free speech signals were made and treated with analysis of variance for differences. Experimental data were also arrayed in graphic form to show trends.

III. RESULTS AND DISCUSSION

A. Intelligibility—Fig. 2 shows the intelligibility of both words and sentences as heard in a given constant S/N ratio. To determine the extent of possible score, one of the test tapes was presented to a group of 40 listeners without any noise masking. A score of more than 98 per cent on both words and sentences was achieved, indicating almost perfect reception under excellent reception conditions. Data for listening sessions with speech produced in quiet, 70, 80, and 100 db of speaker-masking appear in Fig. 2, scores for the 90 db recording level being unfortunately not available, due to an administrative error in giving the tests. The regular behavior of the adjoining conditions would indicate, however, that similar results would have been obtained.

Of immediate interest is the difference in intelligibility scores between the quiet-produced and noise-produced speech. It may be seen that the first level of noise in the speaker's ears (70 db) resulted in speech 35 per cent more intelligible in respect to words, 27 per cent more intelligible in respect to sentences. From that level on, no statistical changes in scores are noted. It is apparent, therefore, that throughout the range tested, no advantage was gained by the speakers from the heavier masking levels used during recording. The curves also indicate that during the steady-score region of 70 to 100 second, because such type of intensity reduction is also employed in aircraft broadcast circuits The total range of limiting involved in these tapes amounted to approximately 10 db

After re-recording, an overlay of wideband random noise was recorded on the test tapes The noise overlay was recorded at a level of 4 db lower than the peak values of the speech signals, both speech and noise being read on the same VU meter As a check, the completed tapes, speech signals plus noise overlay, were run through a graphic level recorder, Sound Apparatus Co, Model HPL The resultant tracings verified the speech peaks as being 4 db above the noise level Fig 1 shows this setup schematically

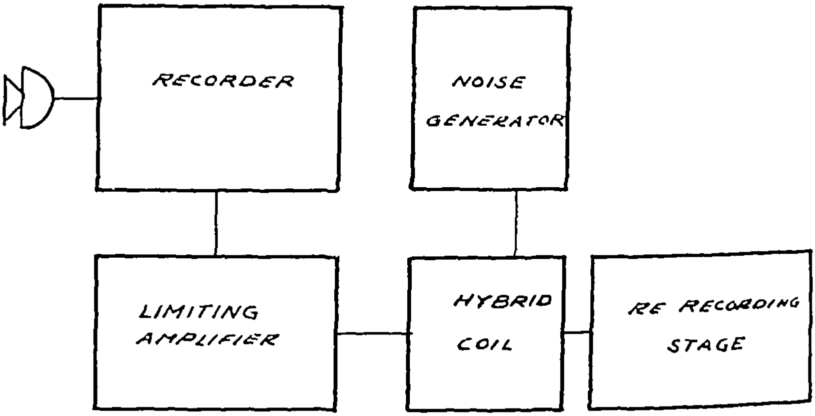

Fig 1 Schematic Diagram of Stimulus Preparation

C Listeners—Listeners were 204 AFROTC cadets at The Ohio State University They were divided into five groups of about 40 persons each

D Test Administration—All listening groups were instructed in the same manner on the mechanics of filling out the test blanks Stimuli were then administered with an Ampex 600 tape recorder and an Ampex 620 speaker-amplifier system to listeners seated in an average-size classroom The nearest listeners were approximately six feet from the loud-

TABLE I

LEVEL OF SPEECH OUTPUT UNDER CONDITIONS OF BROADBAND RANDOM NOISE MASKING AT THE SPEAKER'S EARS

Condition	Words (db)	Diff (db)	Sentences (db)	Diff (db)
Quiet	65 0		68 8	--
70 db	70 8	5 8	71 9	3 1
80 db	71 9	1 1	72 8	0 9
90 db	72 8	0 9	73 9	1 1
100 db	74 1	1 3	74 9	1 0

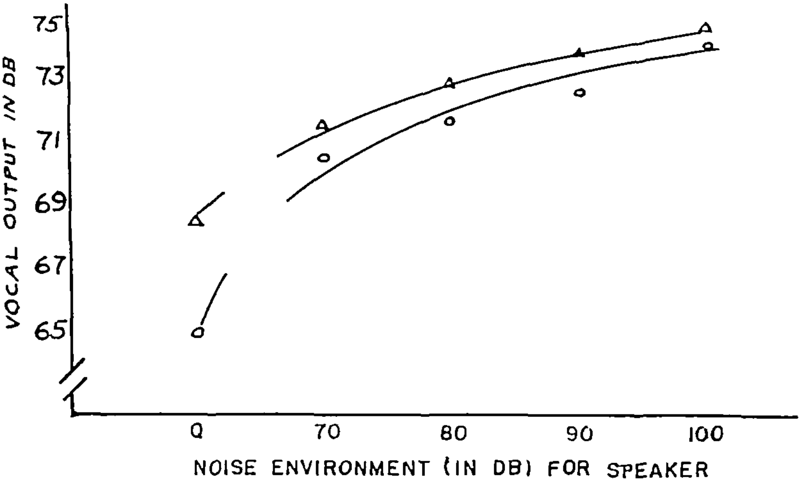

Fig 3 Increase in vocal output with increase of masking level at the speaker's ears.

0 38 db /db From his description of procedure it is possible that this higher figure might reflect some measurement of breath blast caused by microphone placement in his experiment The trend of the tabled values is shown in Fig 3 An interesting point here is that in all conditions the level for spondee was less than for sentences, both readings being taken on maximum peaks of the utterances

2 *Duration Changes*—The same recording traces measured above for intensity changes yielded the comparative duration measurements tabled below

As in the case of intensity, increased masking level resulted in a steady increase in duration, with the greatest difference db the context offered by the sentence settings resulted in about 10 per cent more intelligibility. From these results we would assume that a real and sizeable increase in the intelligibility of speech is realized by introducing some degree of noise into a speaker's ears. It may be possible that the same amount of increase might be effected with less masking noise, and it is also possible that masking levels higher than 100 db might produce different results.

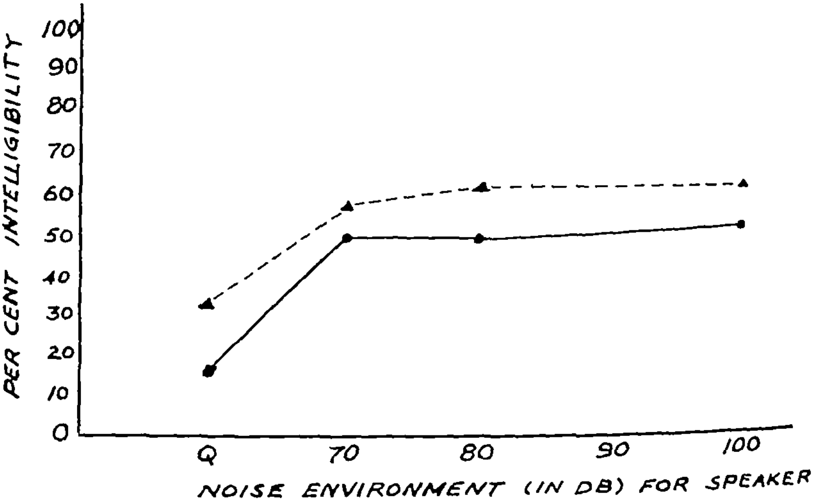

Fig. 2. Intelligibility of words and sentences spoken in various levels of noise and heard at a constant S/N ratio of zero db.

B. Physical Measures—*1. Intensity Changes*—Although intensity of the voice did not contribute to the intelligibility results, the original recordings could be measured to estimate the effect of speaker-masking on his production levels. The initial stimulus tapes were measured on the graphic level recorder to determine both duration and intensity. Results re .0002 dyne/cm^2 are shown in Table I.

The largest intensity increase comes, both for words and sentences, when the first level of masking is employed. After that, succeeding increments of 10 db masking produced an average vocal increase of approximately 1 db. This estimate of 0.1 db/db differs from a previous estimate by Korn[3] of

TABLE I

LEVEL OF SPEECH OUTPUT UNDER CONDITIONS OF BROADBAND RANDOM NOISE MASKING AT THE SPEAKER'S EARS

Condition	Words (db)	Diff (db)	Sentences (db)	Diff (db)
Quiet	65 0	—	68 8	—
70 db	70 8	5 8	71 9	3 1
80 db	71 9	1 1	72 8	0 9
90 db	72 8	0 9	73 9	1 1
100 db	74 1	1 3	74 9	1 0

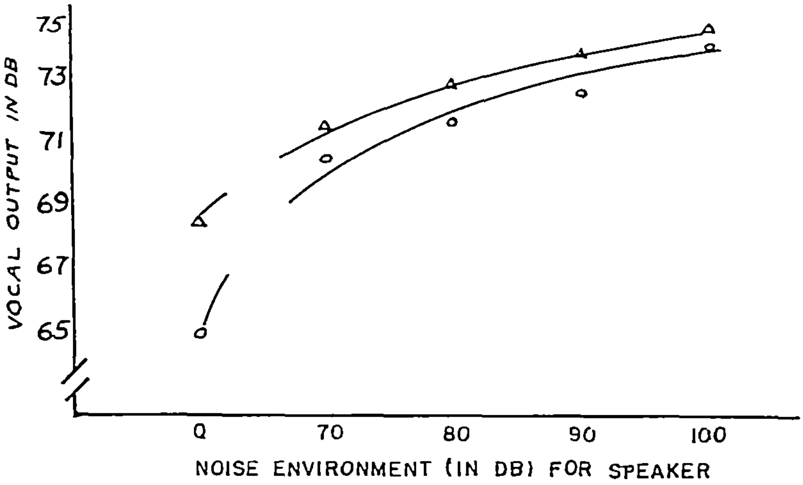

Fig 3 Increase in vocal output with increase of masking level at the speaker s ears.

0 38 db /db From his description of procedure it is possible that this higher figure might reflect some measurement of breath blast caused by microphone placement in his experiment The trend of the tabled values is shown in Fig 3 An interesting point here is that in all conditions the level for spondee was less than for sentences, both readings being taken on maximum peaks of the utterances

2 *Duration Changes*—The same recording traces measured above for intensity changes yielded the comparative duration measurements tabled below

As in the case of intensity, increased masking level resulted in a steady increase in duration, with the greatest difference

TABLE II

DURATION (IN CENTISECONDS) OF WORDS AND PHRASES PRODUCED UNDER CONDITIONS OF BROADBAND RANDOM NOISE MASKING

Conditions	Words	Diff	Sentences	Diff
Quiet	67.0	—	170.0	—
70 db	77.0	10.0	197.0	27.0
80 db	84.0	7.0	202.0	3.0
90 db	86.0	2.0	210.0	8.0
100 db	88.0	2.0	213.0	3.0

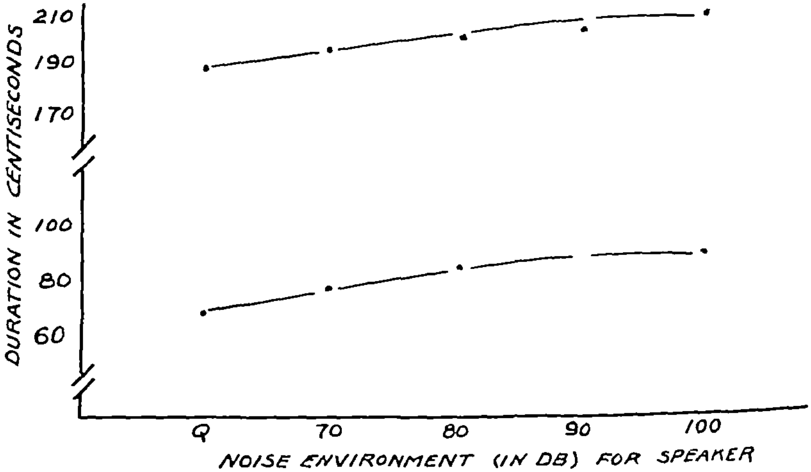

Fig. 4. Increase in duration of words and sentences with increase of masking in speaker's ears

coming with the first onset of the masking noise. Duration functions for the two types of test material are shown in Fig. 4.

Since the intensity factor had been controlled, it cannot be held accountable for the observed increase in intelligibility score associated with noise-produced speech, and in view of the fact that duration changes from one condition to the next were so small as to be statistically insignificant, we should most logically look to other dimensions of the voice for the reasons. The answer may lie in the area of less well defined measures, such as quality and stress, or in the relationships between the sequences of the phonemes making up the speech signal. Suffice it to say, however, that the magnitude of intelligibility change between the first and second experimental conditions might make it well worthwhile to attempt further exploration and application of it The notion of a device for military communication would seem to be feasible for immediate development after additional tests on the range of speaker masking between quiet and 70 db to discover minimum masking level Further studies should also be made on the extent of speaker accommodation to the masking influence The stable and statistically nonsignificant intelligibility scores obtaining in test materials produced under noise conditions of this study may also offer a tool to the audiologist who employs live voice presentation of tests

IV CONCLUSIONS

From the evidence presented above it is concluded that

1 There is a measurable and important increase in the intelligibility of both words and sentences produced by speakers operating with a broadband random noise mask in their headsets

2 The intelligibility values of speech produced under 70 db of masking were statistically equivalent to those produced under 80 and 100 db of masking

3 Plots of both mean duration of speech elements and vocal output show a regular increase with increase in speaker masking

4 The range of masking between "Quiet," (estimated by curvilinear extrapolation to be approximately 54 db) and 70 db of masking needs further exploration to determine additional points on both the intelligibility and vocal output curves, and it is suggested that live voice tests for hearing evaluation consider the use of sufficient speaker masking to effect the vocal stability observed in this study

5 It is recommended that the observation of increased intelligibility be put to operational test in aircraft circuits

6 It is recommended that the aforementioned operational test, if successful, should result in the engineering of a device for emergency use in air-ground communications for speakers in relatively quiet speaking environments

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A COMPARISON OF PICTURE RESPONSE AND HAND RAISING TECHNIQUES FOR PURE TONE AUDIOMETRY WITH YOUNG CHILDREN

BRUCE M SIEGENTHALER,
and
HARRIET KAPLAN,

The Pennsylvania State University,

University Park, Pa

In order to teach the child with a hearing loss to utilize his hearing to his best advantage, an early educational program is necessary This requires early detection of reduced acuity, and it becomes desirable that hearing testing techniques be developed for use with the young child

Among the methods in current use for testing young children are noise makers, speech reception, subjective pure tone audiometry, and PGSR Pure tone audiometrics are preferable to measurement with noise making apparatus and speech for at least part of the testing protocol, because the audiometer gives information about acuity at specific frequencies, and intensity levels are calibrated In some quarters the PGSR test for children is not considered desirable (Although pure tones are used, validity and reliability of testing are questioned because of subjectivity in interpreting results and difficulties in conditioning. In addition, PGSR sometimes is considered to be unpleasant for the child and detrimental for follow-up testing and training). For these reasons subjective pure tone audiometry continues to be the method most generally preferred for testing the hearing acuity of children, however, many children will not respond to pure tone audiometry when the standard response is used (*i.e.*, when the child is expected to raise his hand when he hears the tone). The test procedure must be altered so that suitable responses can be obtained. Pure tone test procedures for children should satisfy at least the following criteria[1,2]

1. Simple association between pure tone stimulus and response.
2. Motivate the child.
3. Take into account child's short attention span.
4. Require only a gross motor response.
5. Not require a verbal response.
6. Aid the examiner to gain rapport.
7. Produce valid and reliable results.
8. Preferably require only one examiner.
9. Allow monaural measurements.
10. Be economical.
11. Require only simple manipulation of apparatus.

Although the standard pure tone audiometry method satisfies some of these criteria, in several important aspects it may be improved upon.

Attempts to devise pure tone audiometric procedures for children have centered mostly around techniques for motivating the children to listen attentively and to respond appropriately. To accomplish these goals a number of varieties of the peep-show technique have been devised.[3,4,5] In all cases, the basic situation is that the child is rewarded for making a correct response when the tone is on, and he is not rewarded if he responds when the tone is not on. Other techniques for pure tone testing with children have been to associate objects with the audiometric tones, and to carry on pre-testing training programs to associate sound with a response.[6-8,9]

Although the literature on methods for testing the hearing of young children is growing, little has been done to compare the results of acuity measurements made using various subjective techniques. It was the purpose of this study to compare the standard technique (hand raising) with a picture response technique (modified peep-show) for pure tone hearing testing of pre-school children. The two response techniques were compared with respect to eight criteria, presumed to be important for evaluating a hearing test, mentioned below.

PROCEDURE

Thirty-nine normal hearing children were used for the study. They were pupils at the nursery school of The Pennsylvania State University, and all were children of faculty members of the university, or of business men of the town. Their chronological ages ranged from three years three months to five years two months. Their mental ages, according to a Stanford-Binet test, ranged from three years five months to six years nine months. The average I.Q. of the children was 121. There were 19 males and 20 females. (Although as a group the children were of superior mental ability, this factor would not be expected to be critical to interpretation of the experimental results. Each child acted as his own control when comparing the two test methods.)

A modified peep-show apparatus was used for part of the experimental testing. Switching circuits were arranged, so that if a child heard a tone in his earphone (monaural) and pressed the top of a box on the table in front of him, the lights in the room went off and he saw an attractive colored picture of an animal projected on a screen. If he pressed the box top when there was no tone, there was no such reward. A standard pure-tone audiometer was used. The animal pictures were on 2x2 inch slides, and projected by a semi-automatic slide projector. If the child became disinterested in a picture the examiner pressed a button attached to the projector, and a new picture became available. Testing was done in a quiet room near the nursery school. The same room and audiometer were used for the standard procedure, but the child was expected to raise his hand when he heard the tone Children were alternated during the testing program, so that half of them had their left ears tested first and half had their right ears tested first, half were tested with the picture response technique first and half were tested by the standard hand raising technique first It was attempted to give each child both tests in both ears for frequencies 1000, 2000, and 500 c p s, in the order mentioned Approximately two weeks after the initial testing each child was given the complete battery test again

The two test procedures were compared on the basis of the following eight criteria

1. Three frequency average threshold
2. Test reliability
3. Time required to orientate child to the test
4. Ease of orientation
5. Number of false responses
6. Three frequency threshold test time
7. Per cent of three frequency tests completed
8. Child's preference

Not all children could be given the complete battery test Some cooperated during one of the tests but refused the other, or occasionally only a partial test could be obtained on an ear, therefore, in the following analyses the number of cases considered does not always reach 39, and often the number is different for the various considerations

RESULTS

Three frequency average threshold—The average threshold for the three frequencies on a single ear of a child was computed and used as the threshold value Table I shows the means of these threshold values for the two test methods for left ears, and for right ears on the initial test, and on the retest The mean thresholds were compared, using the t test for related samples Only children on whom complete tests could be obtained were included It can be seen that in all comparisons the picture response technique gave more acute mean thresholds than did the standard response method

Only for the right ear on the retest did the difference between means fail to reach the 10 level of statistical significance It also will be noticed that the retest thresholds are more acute than the initial test thresholds Picture response thresholds averaged about 3 db more acute than than response thresholds on the initial test

Test Reliability—To measure test reliability the test-retest threshold value 0, 0-5, and more than 5 db from the initial

TABLE I

MEAN DB THRESHOLDS AND t TESTS

	Picture	Standard	N	t	σ_{MD}	P
A D test	9 0	12 1	19	2 79	1 10	02
A S test	8 6	11 3	20	1 98	1 14	10
A D retest	6 8	7 4	20	38	1 41	70
A S retest	5 6	8 8	20	1 94	1 10	10

TABLE II

PER CENT OF EARS SHOWING DB VARIATIONS IN THRESHOLD BETWEEN TEST AND RETEST

c p s	PICTURE N	0 db	0-5 db	<5 db
500	52	35	79	21
1000	53	26	77	23
2000	53	43	81	19
Mean %	—	35	79	21

c p s	STANDARD N	0 db	0 5 db	<5 db
500	36	33	69	31
1000	36	50	78	22
2000	36	33	75	25
Mean %	—	39	74	26

percentages of all ears (both left and right) deviating in threshold value 0, 0-5, and more than 5 db from the initial test on the retest were computed for each frequency, and are shown in Table II Approximately one-third of the ears had 0 db deviation for each method, and approximately three-fourths of the ears had deviations of 5 db or less from test on retest for each method Despite the observed per cent differences between methods for individual frequencies, the differences appear to balance out, and in general both methods appear to have similar reliabilities. (Although it is not shown in Table II, inspection of the original data indicated that in most cases the retest thresholds were more acute than the initial test thresholds. This trend was seen in Table I.)

Orientation Time—When a child entered the testing room he was made to feel comfortable and induced to sit at the table holding his switching box. After the tester demonstrated wearing the earphones it was possible to put the phone on the child, usually without difficulty. The timing of the orientation began when the earphones were on the child, and ended when the child gave three correct responses to the presence of a 1000 c.p.s. tone presented at 50 db hearing loss. Verbal instructions and demonstrations were used to teach the child the test. The mean time required to orientate the children who were given the standard response test first was compared with the mean time required to orientate the children who were given the picture response test first. (It will be recalled that in the subject group half were presented the picture response test first, and half were presented the standard response test first.) The numbers of children in the two groups for this comparison were not the same because some children could not be orientated to one or the other tests. For the 18 children orientated to the picture response test first, the mean time required for orientation was 87 seconds; the 15 children who could be given the standard response test first had a mean orientation time of 155 seconds. A t test computed between these two means gave a value of 1.80, significant between the .05 and .10 levels.

Ease of Orientation—A judgment was made by the examiner as to the ease of orientating each child to the first test he was given. The basis for this judgment was partly on the amount of time it took to orientate the child, but largely on the degree to which his interest could be aroused and held during the orientation, and general impression of his quickness to gain insight into the task required. Of the children given the standard response test first, 70 per cent (14 children) were easy to orientate, 15 per cent (three children) were difficult to orientate, and 15 per cent (three children) were impossible to orientate. For children given the picture

test first 79 per cent (15 children) were easy to orientate), 5 per cent (one child) was difficult to orientate, and 16 per cent (three children) were impossible to orientate Although there was a slightly greater proportion of children easy to orientate to the picture test procedure, the difference between this proportion and the proportion easy to orientate with the standard response technique was not statistically significant according to a t test (t 50, P 60)

In general, those children who were easy to orientate by one technique were easy to orientate by the other technique when it was given second in the testing sequence Where differences existed, they always were in favor of the picture test method For example, some children given the picture test first and easy to orientate were difficult or impossible to orientate to the standard response test when it followed

TABLE III

MEAN TEST TIME IN SECONDS FOR A THREE FREQUENCY TEST

	Picture	Standard	N	σ_{MD}	t	P
A.D	246	230	14	24 42	68	60
A S	310	261	20	19 56	2 48	05

Consistency of Response—Consistency of response was measured by noting how many times each child made responses when there was no tone present for each of the tests The mean number of false responses made during the standard test was two, during the picture test the mean was 1 75 A t test between these mean values was not significant (t 16, P 90)

Three Frequency Threshold Test Time—Timing of the threshold testing began after completion of the orientation, *i e*, after the child had made three successive correct responses Because some children could not be tested in both ears for one or both of the test procedures, test times for right and left ears were separated, and in the analysis only ears which could be tested by both methods were considered to make possible a match groups t test Table III shows the test times and t test results It can be seen that the

standard response method required less time than the picture response method, but the difference was significant for only the left ears. (It was the examiner's impression that the picture response test required longer time because the children enjoyed seeing the pictures so much.)

Per Cent Complete Tests Obtained—Not all children could be tested completely (three frequencies in both ears) with both response methods. Some could be tested in one ear only by a given method, and others could not be tested at all. Table IV shows the per cent of the 39 children who could not be tested in either ear, who could be tested in one ear only, and who could be tested in both ears by each of the methods. Each child was tabulated for his testing with the picture test and for his testing with the standard test. Thirty-eight

TABLE IV

PER CENT OF THREE FREQUENCY TESTS OBTAINED
(39 Children)

STANDARD	PICTURE No Test	One Ear	Two Ears
No Test	18	2	21
One Ear	0	10	10
Two Ears	0	0	38

per cent (15 children) could be tested completely by both methods, 10 per cent (four children) could be tested in one ear only by both methods, and 18 per cent (seven children) could not be tested by either method, however, it will be noticed that 21 per cent (eight children) could be tested in both ears with the pictures, but not at all with the standard response method, and that 10 per cent (four children) could be tested in both ears, using the pictures, but in only one ear by the standard method. Thus a total of 69 per cent (27 children) could be tested in both ears by the picture method, but only 38 per cent (15 children) could be tested in both ears by the standard response method. (In this analysis if a child could be tested for only one or two frequencies in an ear, the result was not counted as a test for that ear.)

Child's Preference—At the end of an initial testing session

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with respect to ease with which children can be orientated to give correct responses

5 There is no significant difference in the number of false responses given during administration of the two tests

6 The picture testing procedure takes longer for the obtaining of thresholds at three frequencies In the present study the difference was statistically significant for only the left ears of the subjects, for these ears the mean difference was about 50 seconds

7 With respect to the success with which a test at at least three frequencies can be done, the picture response method has a clear advantage over the standard response method

8 Children prefer the picture response test method

When considering these eight criteria for comparing the two test techniques, the standard response method is supported only by the criterion of test time The criteria of reliability and number of false responses demonstrated no support for either method over the other The picture response method was supported by the other five criteria

It is questionable whether the issue of which test is superior should be decided by the number of criteria in favor of each, rather, the relative importance of the various criteria should be considered Although the standard response method took less time to administer after orientation, the difference was more than cancelled by the shorter orientation time for the picture method The picture method produced slightly more acute thresholds than did the standard response method, but this difference is of little numerical or theoretical importance Because any threshold is determined by definition, *i e*, hearing acuity is judged in terms of whether a given response is obtained, it is to be expected that different definitions of threshold (different responses required) would give different threshold db values However, the picture response method was supported by the very important criteria of interest on the part of the children and per cent of children who could be tested Gaining a child's interest, cooperation, and test thresholds are of major importance, both for clinical examination for a child he was asked which test he liked better, and which test he would like to have if he were to be tested again, also, the child's parents were sent a letter requesting them to ask their child prescribed leading questions about what happened in school that day, and to note his responses. On the evening that a child was tested the parents were interviewed by telephone regarding their child's comments. The child's statements to the examiner and the reports made by the parents were transcribed and presented to five disinterested judges. The judges were asked to categorize each child's pattern of responses into the categories, "Definite preference for the standard test," "Slight preference for the standard test," "No preference," "Slight preference for the picture test," and "Definite preference for the picture test." These categories were assigned the numerical values 1 to 5 respectively, and the numerical values given each child by the five judges were totaled. If the total for a child were more than 15 he was considered to have preferred the picture test, if less than 15 the picture test, and if it were 15 he was considered to have shown no preference. By this procedure 91 per cent (30 children) showed preference for the picture response test, 3 per cent (one child) preferred the standard response test, and 6 per cent (two children) showed no preference.

DISCUSSION

As a result of these analyses the following conclusions can be drawn regarding each of the eight criterion for comparing the two test procedures.

1. For an initial clinical test of hearing acuity in the middle frequency range the picture response technique gives more acute thresholds than does the standard hand raising response technique. The difference is about 3 db.

2. Reliability of the two test techniques appears to be about equal.

3. Orientation time for the picture response method is shorter than for the standard method. For the present sample the difference was about one minute.

4. The picture response method is slightly advantageous dermal responses Marcus and Gibbs, in 1948 and 1951, were the first to use electroencephalic responses to determine hearing One study was reported by Gidoll in 1952 In 1953, Pearl, et al, reported again on the use of the E E G responses in sleep to evaluate function of the ear Since our first publication in 1956, Goldstein (1956) has reported on the use of the E E G in conscious states as an auditory measurement, and Simon and Emmons (1956) have used these same endpoints

The original goal of all these workers was a clinical one concerning the many children under 4 and 5 years of age, and the many older ones in whom lack of communication is so serious a problem that standard methods do not work. With these patients it is important to be able to measure not only their functioning level, but also to dissect out where and what types of trouble may exist

From the data obtained by reliable standard audiometry it has been possible to infer where almost any disturbance may lie in the auditory system These inferences, however, are only an approximation They do not tell in a detailed way how any particular part of the system is abnormal, furthermore, reliable audiometry is most difficult to obtain in the child, where accuracy is most needed

It is during the diagnostic and planning states in the patient's early years that we need certainly to know whether the child's problem is in reception, in coding the information into nerve impulses, or in transmitting this information to the brain, or if the communication problem might also be higher up in the central nervous system involving the decoding process, the awareness, or the integration of this information with other knowledge and memories, so that synthesis into action or speech results (Hardy, 1956), or if the delayed language might be due to psychic forces, so that the child finds that only a certain level of sound or speech is compatible with a comfortable existence It might cost him too much emotionally to pay more attention, or invest more in the area of communication by sounds

For the evaluation of each of these components we need to and for further audiological work with the child In these respects the picture response method seems to have a clear advantage over the standard response method for testing pre-school age children

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FURTHER CONTRIBUTIONS TO THE E E G METHOD OF EVALUATING AUDITORY FUNCTION

A J Derbyshire,
Harper Hospital,
and
M McDermott,
Children's Hospital,
Detroit, Mich

In the year 1939 the Davises first described the E E G responses to sound occurring in sleeping subjects This most accessible fact lay unused, except in animal work until 1948, when Doerfler used the E E G instrument to record electro-most common and most useful one we can identify Less often, instead of remaining suppressed, the pattern may gradually increase its voltage, rising to a level higher than that seen before stimulation This build up shows a latency of 0 5-1 0 sec

Third, there are frequent off-effects, of typical K formations, or brief periods of voltage reduction When working

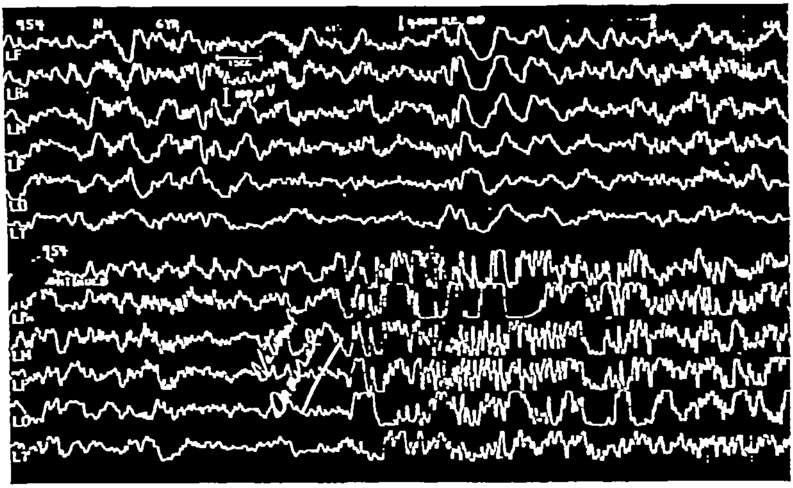

Fig 1 This E E G pattern shows three of the four possible responses to 5 seconds of pure tone The two strips are continuous. The E E G patterns are recorded between both ear lobes and LF (left frontal area) LPm (left precentral) LM (left central) LP (left parietal) LO (left occiput) LT (left mid-temporal) This is a normal hearing six-year-old patient. Arrows mark on and off of a 4000 c.p s tone at 80 db to the right ear A K formation begins after a latency of 0 8 seconds (on effect) There is a suppression of fast rhythms in frontal areas from 1 4 sec. to 3 6 sec. (continuous effect) although delta (1-2/sec.) persist. There is no off effect other than the return of 11/sec spindling with the cessation of tone Seventeen seconds after the stimulus starts there is a dramatic change of pattern signaling an arousal. The child woke up stirred and fell asleep again. The words 'natural arousal written on the record were our notes meaning that no other stimulus was identifiable in the 17 sec. interval.

near threshold these are often stronger than the on-effect. Just as the conscious patient often misses the onset, but detects the turning off, of the presented tone when at or near threshold

Fourth, there is a late effect Any time within about 25 seconds of turning on a tone of 5 seconds' duration there may be a relatively sudden change in the entire pattern of the develop standardized methods that have a known reliability, and at the same time ease of accomplishment clinically

The E E G audio method in sleep, and in repose, offers procedures which put aside the psychic factors of making decisions These electrical patterns tap the central nervous system after at least reception, coding and transmission have occurred It is probable that the E E G audio response is not at the synthesizing or motor levels It is likely that these responses arise from a secondary pathway that splits off the main specific projection path for hearing somewhere in the brain stem or thalamus This side path activates a diffuse system that in turn stimulates the cortex, both generally and specifically The result is our E E G response, and we believe an accompanying change in patients' sleep level When the results of E E G audio tests with known reliability are compared to standard audiometry, and to electrodermal audiometry, etc, then we can begin to establish where, to what degree and what kinds of information loss have occurred in our patient's communication channel

Of primary importance is a careful description of the detectable responses used in E E G audiometry in sleep We began by searching for the K formations described by Davis They were most clear and useful, but required a moderate to deep stage of sleep, and did not cover all of the various responses They were better seen in response to clicks rather than pure tone There were many times when a reduction of voltage or other changes were more apparent

We find we can describe four component parts to the total response to a pure tone of two to six seconds' duration (see Fig 1) There is, first, an on-effect with a latency of 50-500 msec (average 250 msec) This is most often a K formation, or a fragment of one or a spindle of 14/sec waves Whether or not a K formation occurs, there is, second, a reduction of voltage, particularly of the faster frequencies in the pattern with a latency of 200 to 600 msec (average 400 msec) This suppression may be brief or may continue throughout the 2 to 6 seconds the tone is presented Although this is not the only kind of response at this point in time, it is by all odds the

These repeats were done because we were dissatisfied with the results on the first test for one reason or another Here again the variation was ±18 db We believe these express the worst possible errors in the method, and before giving a final statement we intend to describe more fully the nature of the most reliable response and the rules for its detection. We believe we can do better, because the consistency within one test is much better than the figure of ±18 db When there is deviation in our comparisons it is consistent and applies to all points in that test

Our first attempts to solve the reasons for these differences is the work we are reporting here We will describe these E E G responses as a function of intensity over a wide intensity range It should be emphasized that thresholds, regardless of their usefulness, are but a series of points along one edge of a vast field of sensory experience. A threshold is a function tested at its limits, where it is most likely to be non-linear At threshold the mechanism may function on some other principles than it would at the levels used for ordinary communication Finally a threshold is where error is likely to be greatest

There are two aspects of E E G responses which we can measure easily as functions of intensity one is the latency of the response, the other is percentage of positive responses identified at each intensity level, and these can be studied in repose and sleep states in the same patient In fact, on several occasions it has been possible to record on the 8 channel E E G machine a signal of the tone presented, a signal activated by the patient's closing a micro-switch held in his hand, the potentials of the muscles used for that action, the E E G , the E D G and either a pneumograph of the chest or a plethysmograph of a finger (see Fig 2) This record may start in repose, and after obtaining the function relating intensity to response, the patient may fall asleep, and we can repeat the function in sleep The percentage of positive responses as a function of intensity can then be compared in repose and sleep

It is often important to plot the latency in seconds as a

E E G, signifying a different level of sleep The subject may awaken at such a time, or the change may be only transient Rarely the E E G may show a deeper level of sleep

These responses do not all occur with every stimulus They may each vary in amplitude, duration and complexity, in fact, if one stimulus is repeated rhythmically, as Chafetz and Cadilhac (1954) have shown, the response tends to vary in complexity, amplitude, and ease of detection It comes and goes over periods of seconds to minutes Peculiarly, not all cortical areas wax and wane synchronously, so that the most clearly visible response may shift from area to area The form of the E E G responses show little evidence of relationship to intensity of stimulus as we test for them This relationship of form of response to intensity could well be masked by our method of study It is clear that since our latencies vary from the shortest of 50-70 msec to well over 2 0 seconds we are dealing with a complex system In fact, because the response is, *1* independent of age (down to 2 months), *2* has such a long and variable latency, *3* is most prominent in the fronto-central areas, we have proposed the idea that the response is evoked in the cortex, not by the primary projection path to the temporal lobe, but by a side path to the reticular formation of the midbrain or thalamus The question we cannot answer is whether or not every E E G change we identify could be heard by the patient if he were conscious and attending There is the possibility of sound arriving through the ear into the central nervous system that the patient could not consciously detect or hear

Accepting these E E G changes in sleep as responses to pure tone, the next question is what is the threshold of this E E G response, and what relations does it have to conscious hearing We define as threshold the intensity level producing 50 per cent positive response

The comparison of E E G threshold with standard audiometric thresholds in a group of children in a deaf school showed a deviation of ±18 db Recently we determined the variation between repeat E E G audiometric tests in sleep

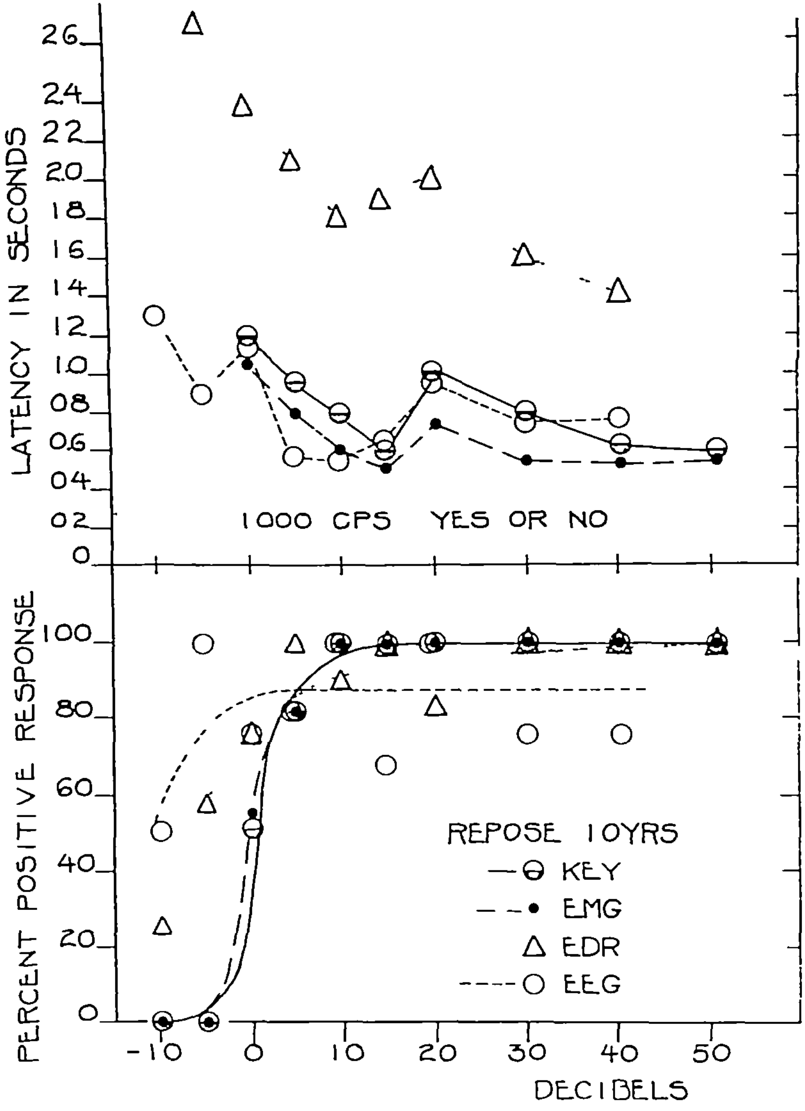

Fig 3 These are the plots of the latencies in the upper graph and the percentages of positive responses in the lower graph for 4 of the phenomena recorded polygraphically This data is obtained from the same patient in repose as shown in Fig 2 except that this is for 1000 c.p s to right ear Note that the latency of Alpha suppression is shorter than latency of muscle potentials till the level of 15 db is reached Above 15 db the muscle has the shorter latency

Key—Closure of micro-switch held in patient s hand E M.G—electromyal responses from the muscle group for flexing palm and fingers of hand holding key E D R.—Electrodermal responses as potential changes between palm and back of hand E E G—electroencephalic responses from leads covering frontal motor and occipital zones. Decibels in this paper are all relative to 0 db as the normal human threshold for that frequency function of intensity in decibels simultaneously with the per cent response curve Latency approaches infinite duration at some minimal intensity With increasing intensities the latency shortens until it approaches a minimal constant value This curve is so close to an hyperbola that if it is plotted as the reciprocal of the latency against intensity in decibels a straight line results Near threshold the points tend to deviate from the straight line function and may follow some different law, or it may be that since data is difficult to obtain at those low intensity levels in any quantity, inaccuracy makes results unreliable

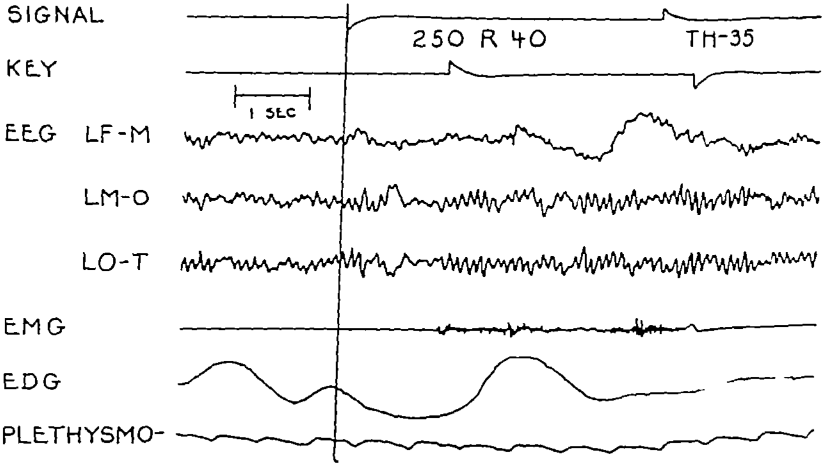

Fig 2 This is a strip of polygraphic recording from a patient in repose showing the responses to a tone of 250 c p s to his right ear at 40 db or 5 db above his standard audiometric threshold The latency of closure of key is 1 4 seconds The latency of suppression of Alpha is 0 7 seconds The muscle potentials appear at 1 3 seconds The electrodermal response occurs at 1 9 seconds while the plethysmograph change occurs at almost 4 seconds With cessation of tone there is opening of key in 0 5 seconds and Alpha suppression in 1 3 seconds while the muscle potentials end in 0 35 seconds

By examining the functions of both latency and per cent response, it is more apparent when an error in reading has occurred In such a case the points at one sensation level on both curves deviate widely from the expected or smooth function By re-examining the raw data for these points one can learn about the errors in judgment likely to be made There is often wide variation around each point, but the consistency

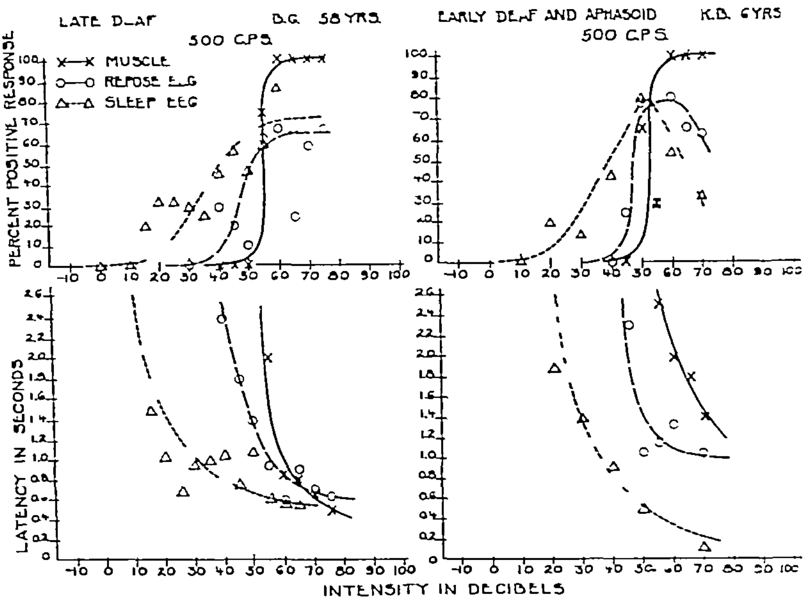

Fig 4-B

Fig 4 A-B This figure presents the plots of latencies in the lower curves and of the percentages of positive responses in upper curves The three individual curves represent the E E G responses in sleep the suppression of Alpha in the E E G of repose and either the muscle potentials or closure of key in repose The four patients are A. G a normal O M. middle aged patient with otosclerosis of some eight years duration B. G an elderly person with deafness occurring late in life on the side being tested and K. B a young child who clinically has evidenced both deafness and language retardation since the age of speech development. These functions were all studied at 500 c.p s

The reversal of latencies between Alpha suppression and key is not seen in all patients in the range studied The functions of the unconscious responses (E.E G) arrive at a maximal percentage and minimal latencies about the intensity level at which the conscious response is making its most rapid changes.

On patient K. B is indicated *a phenomenon* which is not rare The per cent of positive E E G responses falls off at intensities higher than those which achieve the maximum. This suggests inhibitory phenomena. (Hardy 1957)

when working at minimal intensities It is most obvious that the subject hears, even though he decides not to respond

At minimal levels of intensity the suppression of Alpha appears as the first response in time and the muscle potentials come later in time About 20 db above this level there is a trend for reversal The muscle potentials appear first and the Alpha suppression follows We assume that the Alpha activity is suppressed by an increase in attention In the light of this concept, then, the Alpha suppression would be with which the averages yield the same shape of curve convinces us of the presence of the two functions at this low intensity edge of the auditory field

The comparison of these functions with different kinds of communication problems, and the comparison of repose and sleep, bring out information about our original problem of the differences between standard and E E G audiometry

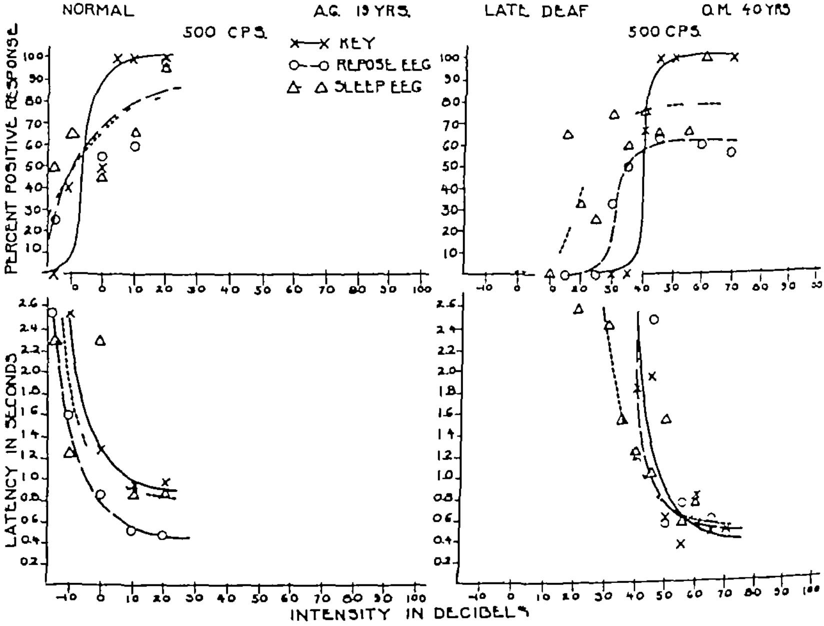

Fig 4-A

An illustration of these functions as displayed by the various end points of response in the waking normal subject are illustrated in Fig 3

The unconsciously controlled components i e, E E G and E D G tend to show a higher percentage of positive responses and shorter latencies than those of the E M G and the key at low intensity levels These responses may reflect the presence in the central nervous system of the information upon which the closing of the key is made It is of interest to see the presence of muscle tension without closure of key mum It appears that the conscious audiometric threshold is the level at which near maximal alertness has been achieved by the tone

J J Groen (1957) has suggested that these curves represent probability functions, in which the coincidental presence of the first two (E E G response in sleep and in repose) might represent activities in the nervous system which cause the third (response of the key) It seems as though each function might represent a nucleus on the way to the cortical surface

The response of the key would reflect cortical activity The Alpha suppression in repose would reflect the action of some nucleus below the cortical level, perhaps in the thalamus The E E G responses in sleep would reflect a still deeper nucleus or center perhaps in midbrain

SUMMARY

The characteristics of responses to tone in the E E G in sleep are reviewed On, continuous, off and late effects are described

The latency of the first identifiable response, and the per cent positive responses are studied as functions of intensity

Three functions are compared

1 In sleep those described above (an unconscious response)

2 In repose the Alpha suppression (an unconscious response)

3 In repose the closure of a key (a consciously determined decision)

The function of per cent positive responses in sleep has the most gradual slope, while the closure of the key has the steepest slope

The latency at minimal intensities is shortest for the E E G response in sleep, while it is longest for closure of key The difference is lost, or the reverse is true at the higher intensity levels

much more likely at low intensity levels, where the signal is hardly distinguishable from the background noise, and an increase in attention is required for detection of the sound When the tone is 20 db stronger, then no change in attentiveness is required for detection, so the Alpha may not suppress, however, we often now find the Alpha suppressed after the appearance of the muscle potentials for closing the key It is probably the increase in alertness resulting from the movement which produces this Alpha suppression

In Fig 4 are shown four pairs of these same curves of latency and per cent positive response related to intensity for four persons (one normal and one deaf from otosclerosis, one deaf late in life and one child with both aphasia and deafness) In each graph are presented simultaneously the three curves found for the key or muscle response, the suppression of Alpha in repose and the E E G response in sleep

The relationships between these three measurements indicates that the consciously determined response of muscle or key has a shift from 0 to 100 per cent positive response over only a narrow intensity range The E E G response in repose has a less steep slope, and rises over a broader intensity range, while the E E G response in sleep has a still more gradual rise or slope The trend, however, is for the E E G functions to arrive at their maximum per cent at the same intensity level at which the key or muscle response suddenly rises to its maximum

The function of the muscle, or key response, expresses the probability of occurrence of a conscious decision This decision is determined by many factors, which are at present being investigated by W Tanner (1956) Over and above the signal to noise ratio these factors include the various values and costs of correct and erroneous judgments within the situation The decision also depends upon the clarity in the patient's memory of the tone for which he is listening, as well as his ability to listen

Since the E E G functions are a correlate of alertness and arousal, it is significant that these reach their maximum at the time when the key response makes its rapid rise to maxi-

SESSION B

May 16, 1957

BEHAVIOR OF THE NEUROGLIA OF THE ACOUSTIC NUCLEI, SUB-CORTICAL CENTERS AND AUDITORY CORTEX, OF CATS INTOXICATED WITH DIHYDRO-STREPTOMYCIN

GERALDO DE SA,

University of Recife, Brazil

Neurotoxic phenomena caused by the use of antibiotics, are well known, however, the specific toxicity of streptomycin for the vestibular system, and of dihydro-streptomycin for the cochlear system, is interesting Literature on the subject is wide, and we should like to remember the papers of Fowler and Seligman[1], Carr, Brown, Hodgson, and Heilman[2], Shane and Laurie[3], Glorig[4], Heck, Lynch and Graves[5], Caussé[6], etc

Considering the neurotoxic phenomena doubtless induced hematically, we tried to verify the behavior of the nourishing element of the nerve tissues, the neuroglia, in the several nuclei of the cochlear pathway, the sub-cortical centers and in the auditory cortex No reference was found to this important complement of the nervous tissue in more than 40 bibliographic sources Taking advantage of the known specific toxicity of dihydro-streptomycin for the cochlear system, we endeavored to bring some light to the confused cochlear pathway and cortical projection on an experimental animal Unable to use the monkey, we chose the cat, whose nervous system has been thoroughly investigated

ANATOMIC AND PHYSIOLOGIC DATA

Stimuli received by the organ of Corti pass the dorsal and ventral cochlear nuclei, from there they go through the

The E E G response in sleep and the Alpha suppression in repose are interpreted as signs of alerting mechanisms of the reticular formation These functions reach their maximum at the same intensity level at which the per cent response for the closure of the key reaches its maximum This suggests that maximal alertness is one element in determining the standard audiometric threshold

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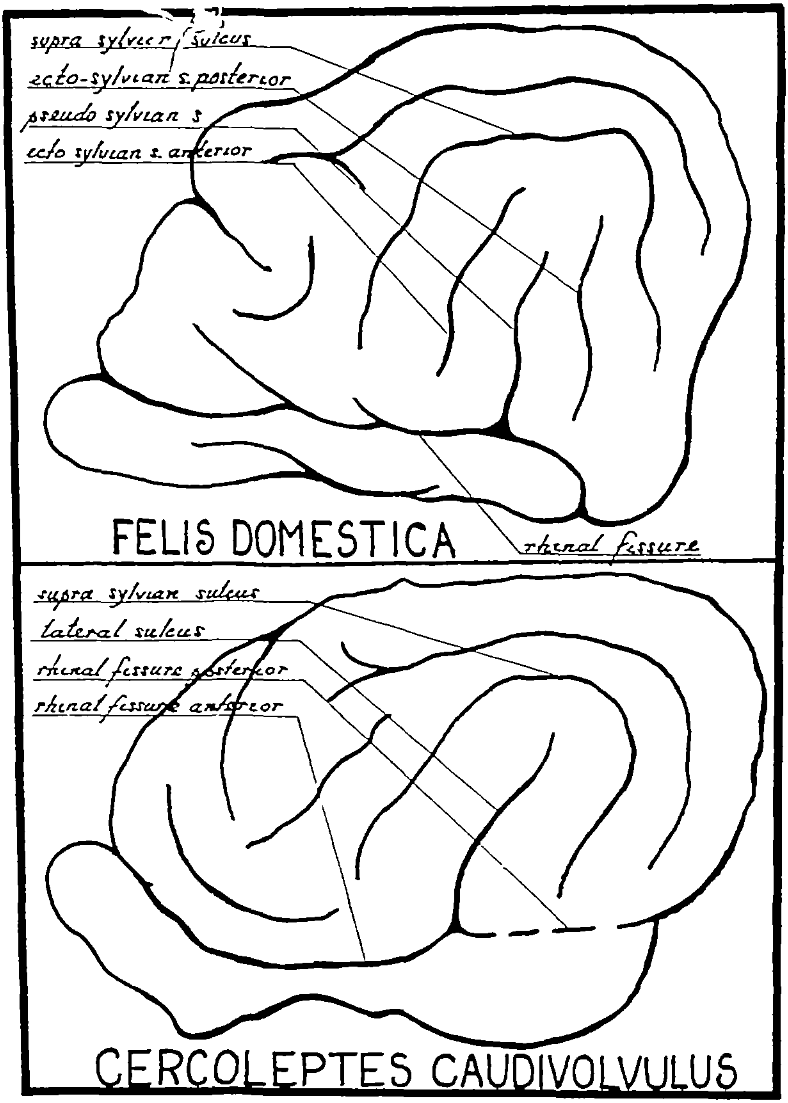

Fig 1

letti, 1915[19], Loreti, 1938[20], Bairati, 1950[21], and Contu, 1953[22], by the Anglo-American School, Penfield, 1924[23], and Robertson, 1900,[24] and by the German School, Nissl, 1904, and Bauer, 1924[25] superior olive, trapezoid body nucleus and the opposite lateral lemniscus nucleus to the inferior colliculus (posterior quadrigeminal tubercle) and to the medial geniculate body, which also receives stimuli from the inferior colliculus and from fibers of the opposite nerve, through the so-called Gudden commissure (Castaldi, 1920[7]). It is evident, that the inferior colliculus has a double action: *a.* Interposed center in the superior pathway, *b.* Reflex center. Cochlear reflex movements of the eyes and neck are so determined. It is, therefore, established that the true acoustic sub-cortical center is on the medial geniculate body, where the acoustic radiation that goes to the cortex originates (Becari, 1943[8]).

The center of the acoustic projection is little known in experimental animals. In the human, it is localized above the the superior temporal gyrus, (Pfeifer, 1920[9]), and constituted by separated striae organized in different physiologic zones, placed according to Campbell[10] and Penfield[11] on the areas 22, 41, 42 of Brodman's chart.

Walker[12] described the acoustic projection on the monkey. Very little is known about the other vertebrates, including the cat, besides Cajal's (1911) demonstration of elements that were similar to the acoustic cells of man.[13] Functional localizations were well observed on the carnivora, but the uncertainty about the acoustic area remained, due to the poorly defined relations of the temporal sulci. The disagreement among writers reached its peak regarding the identification of the so-called ecto-sylvian sulcus.

Fig. 1 shows the lateral views of the brain of the cat, according to Dusser de Barenne[14] and of the cercoleptes caudivolvulus, according to Brodman.[15] The morphologic difference of the topographical arrangements of the sulci of the temporal lobe, mainly the ecto-sylvian sulcus, is clear. In the cat, the sulcus is called pseudo-sylvian and located in front, of the anterior ecto-sylvian sulcus and behind the posterior ecto-sylvian sulcus.

The well-known neuroglia was mainly studied by the Spanish School, Cajal, 1911, 1920[13], Rio Hortega, 1921, 1942[16], De Castro, 1942[17], by the Italian School, Golgi, 1903[18], Ceranimals had their weight and cochlear reflexes controlled every two days The animals were sacrificed by perfusion of the Del Rio-Hortega liquid Distilled water, 240 cc , Formalin, 60 cc , Ammonium bromide, 9 gr , pH = 5

The fixation was controlled daily, and the solution changed every time it became neutral After 15 days of fixation the specimens were frozen-sectioned and submitted to impregnation for 30 days

CHART I
DI HYDRO STREPTOMYCIN INTOXICATION

DAY	CAT N 1			CAT N 3			CAT N 5			CAT Nº6			CAT Nº8		
	—	WEIGHT IN GRAMS	ACOUSTIC REFLEXES	[illegible]	WEIGHT IN GRAMS	ACOUSTIC REFLEXES	[illegible]	WEIGHT IN GRAMS	ACOUSTIC REFLEXES	[illegible]	WEIGHT IN GRAMS	ACOUSTIC REFLEXES	[illegible]	WEIGHT IN GRAMS	ACOUSTIC REFLEXES
5 23-56		1350	PRESENT	0.10	1800	PRESENT	0.10	1750	PRESENT	0.10	1250	PRESENT	0.10	[illegible]	PRESENT
5 24 56			-	0.10		-	0.10		-	0.10			0.10		
5 25 56		1350	-	0.10	1635	-	0.10	1750		0.10	1200	-	0.10	1750	-
5 26 56			-	0.10		-	0.10			0.10		MODERATE	0.10		-
5 27 56			-	0.10		MODERATE	0.10			0.10			0.10		
5-28 56		1428	-	0.10	1795	-	0.10	1800	MODERATE	0.10	1325		0.10	[illegible]	MODERATE
5 29 56			-	0.10		-	0.10		-	0.10		-	0.10		
5-30 56		1450	-	0.10	1820	-	0.10	[illegible]	-	0.10	1400	-	0.10	1825	-
5 31 56			-	0.10		-	0.10		-	0.10		FAINT	0.10		
6 1 56		1500	-	0.10	1560	FAINT	0.10	1900	-	0.10	1430	-	0.10	1950	FAINT
6 2 56			-	0.10		-	0.10		-	0.10			0.10		
6 3 56			-	0.10		ABSENT	0.10		FAINT	0.10		-	0.10		-
6 4 56			-	0.10		-	0.10		-	0.10			0.10		
6 5 56			-	0.10		-	0.10			0.10		ABSENT	0.10		-
6 6 56			-	0.10		-	0.10			0.10		-	0.10		
6 7 56			-	0.10		ABSENT	0.10		-	0.10			0.10		ABSENT
6 8 56		1450	-	0.10	1650	-	0.20	[illegible]	-	0.20	1350		0.20	1650	-
6 9 56			-	SACRIFICED			0.20		ABSENT	0.20		-	0.20		-
6 10 56			-				0.20		-	0.20		ABSENTS	0.20		
6 11 56			-				0.20		ABSENT	0.20		-	0.20		
6 12 56			-				0.20		-	SACRIFICED			0.20		ABSENT
6 13 56			-				SACRIFICED						0.20		
6 14 56	SACRIFICED												SACRIFIC		

The Del Rio-Hortega method as used in the Anatomy Laboratory of the University of Recife includes the following rules

1 After life fixation by perfusion, excision of the nervous system with dissection of the pons, medial geniculate body brachium of the inferior colliculus, inferior colliculus, and cortex, corresponding to the gyri in front, and behind to the pseudo-sylvian sulcus Specimens obtained were submitted to fixation for 15 days in the Rio-Hortega liquid

2 Frozen sections, 15 to 25 micra thick

Barrati and Contu established the glial architecture of the nervous centers, the former in the amphibia and avis, and the latter in the reptilia and mammalia These authors proposed the following classification

Type 1 Architecture of the white substance gliocytes arranged around the myelin sheath, bound among themselves and with the vascular net, by other glial elements, forming a connective apparatus

Type 2 Architecture of the brain stem nuclei gliocytes forming perineuronal sheaths arranged as a connective apparatus with the blood vessels

Type 3 Architecture of the supra axial centers gliocytes articulated with the glial processes and with the vessels

Studying the medulla oblongata of the cat, Contu found glial architecture of the second type, formed by fibrous elements with numerous satellite oligodendrogliocytes In the inferior colliculus the same aspect was seen innumerable oligodendrogliocytes with regular cuboid body, thin, smooth, hairlike processes, scarcely ramified In the young animals, however, the architecture is constituted by protoplasmatic elements, also scarcely ramified, epithelioid elements and small oligodendrogliocytes The former aspect, according to the author, would be the result of age

Some authors reported glial intoxication Among them, Sancez Ibañez and Perez[26] in 1935 performed guanidinic intoxication and observed gliosis and granular degeneration of the processes' cytoplasma

Stigliani[27] in 1940, demonstrated in the toxi-infections a great amount of neuroglia, and writes about glial hyperplasia without any statistical proof, as reported before by Lucaro[28] in 1907, even though affirming that mitosis and amitosis were exceptional on the neuroglia

MATERIAL AND METHODS

Five cats, two male and three female, between eight and 18 months old, were used Meat and milk were their diet One of the cats was used as a control (see chart) The

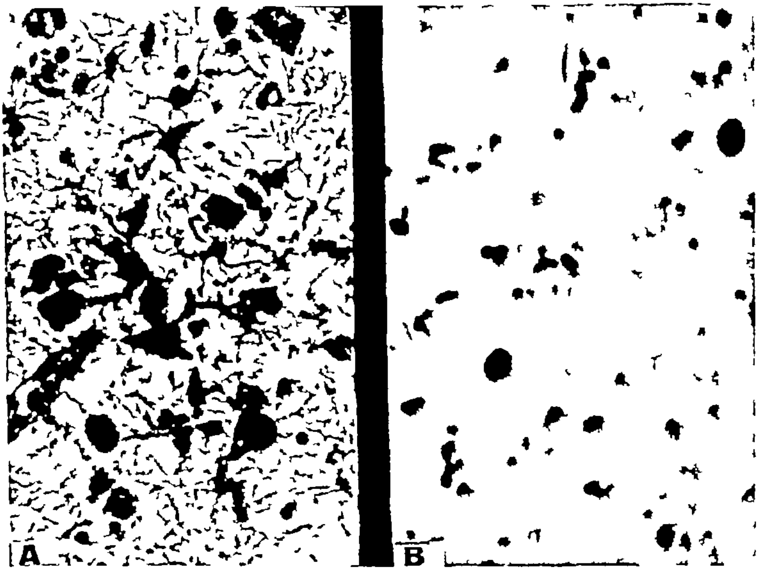

Fig 2
A—Section of cochlear ventral nucleus of control cat—500X.
B—Section of cochlear ventral nucleus of intoxicated cat—500X.
(Del Rio-Hortega Method)

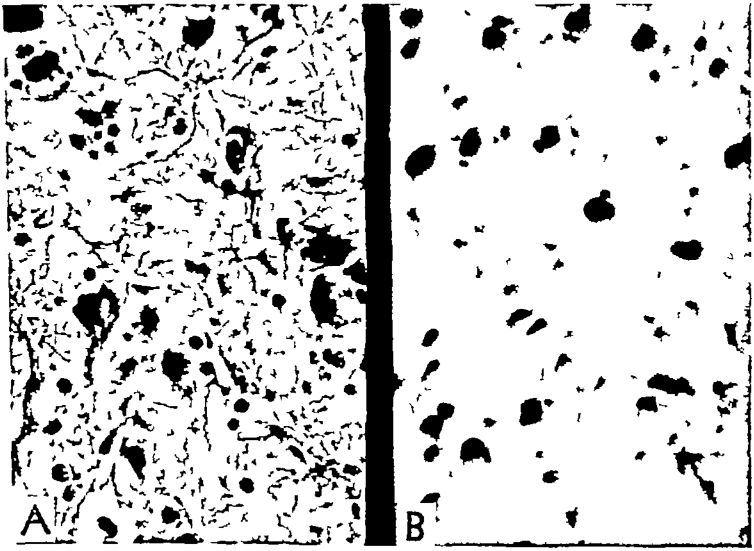

Fig 3
A—Section of trapezoid body of control cat—500X.
B—Section of trapezoid body of intoxicated cat—500X.
(Del Rio-Hortega Method)

3 Re-fixation in the Rio-Hortega for 15 days

4 Washings for one hour in three distilled waters

5 Sections submitted to Hortega's silver, to which was added two to four drops of piridin, for one hour at ambiental temperature, and for 10 to 20 minutes at 50° C

6 Washing for 30 minutes in distilled water

7 Reduction in formaldehyde solution by 5 per cent

8 Washing for one hour in distilled water

9 Turning over of the specimens in a solution of 2 per cent of gold chloride

10 Fast washing in distilled water

11 Reduction for five minutes in a 5 per cent solution of sodium hyposulfite

12 Washing for one hour and alcoholic dehydration followed by mounting of the specimens in *Canada balsam*

Some of the specimens have also been submitted to the Mallory and Iron Hematoxilin methods

EXPERIMENTAL FINDINGS

Sections of the pons, (cochlear nuclei, superior olive, and trapezoid body nucleus), mesencephalon, (inferior colliculus), metathalamus, (medial geniculate body) and cortex, (gyrus between the pseudo-sylvian sulcus and the posterior ecto-sylvian sulcus), were studied

Pons

Control Cat—Glial architecture of the second type was found on the cochlear nuclei, superior olive and trapezoid body Perineuronal sheath formed by fibrous astrocytes and satellite oligodendrogliocytes nicely developing connective apparatus and connections with the blood vessels (see Figs 2, 3)

Intoxicated Cats—Only the nuclei of the gliocytes appear, many with abundant atypical mitosis The glial processes are not demonstrable, and only a few oligodendrogliocytes present thin processes, almost unimpregnated, mitosis more frequent on the gliocytes of the connective apparatus

Mesencephalon

Control Cat—Typical second type architecture on the inferior colliculus Big fibrous astrocytes with many ramifications Many oligodendrogliocytes with thin and smooth processes with little protoplasmatic elements (see Fig 4)

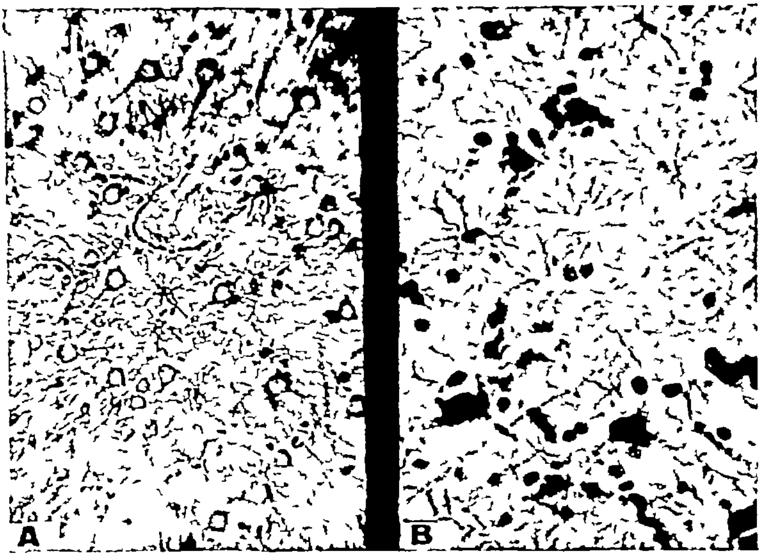

Fig 5

A—Section of geniculate body of control cat—145X.
B—Section of geniculate body of control cat—500X.
(Del Rio-Hortega Method)

Intoxicated Cats—A very different aspect, atypical mitosis and only in very few elements the processes appeared slightly impregnated, most of the processes are non-identifiable

Metathalamus

Control Cat—Glial architecture of the geniculate body of second type, characterized by the presence of few fibrous astrocytes, many protoplasmatic processes and oligodendro-

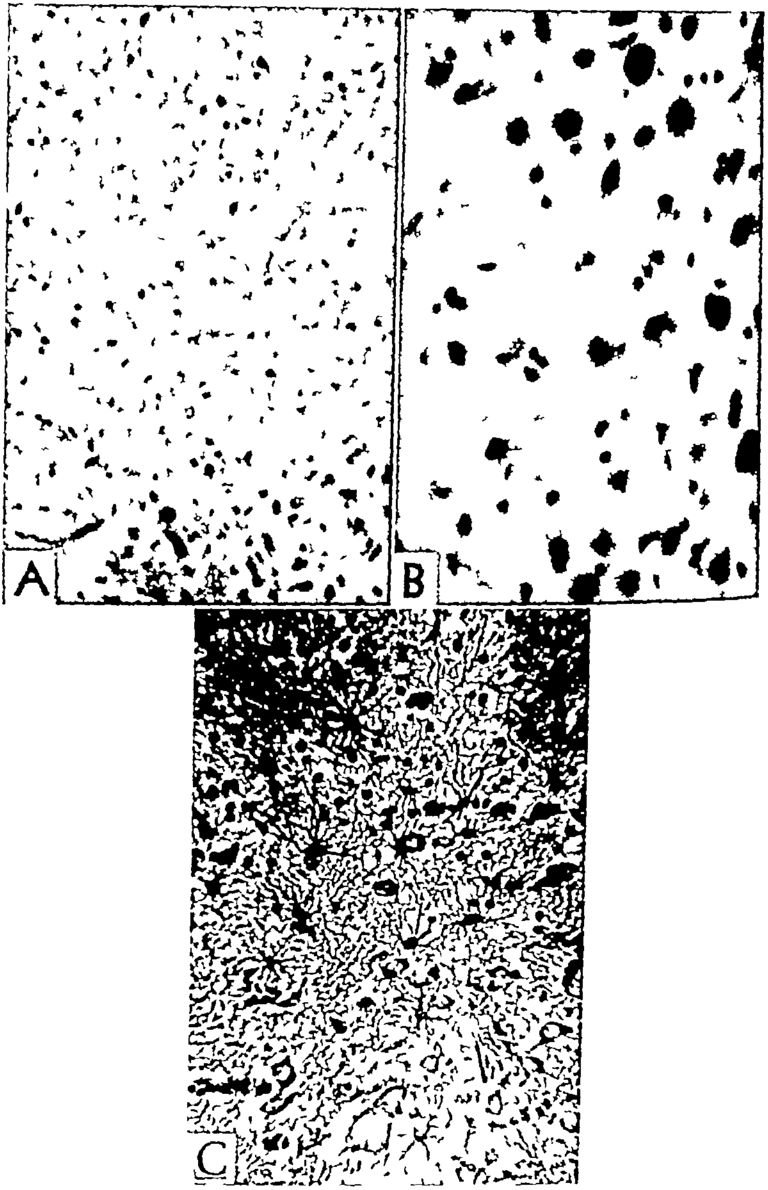

Fig 4

A—Section of inferior colliculus of intoxicated cat—80X.
B—Section of inferior colliculus of intoxicated cat—500X.
C—Section of inferior colliculus of control cat—145X.
(Del Rio-Hortega Method)

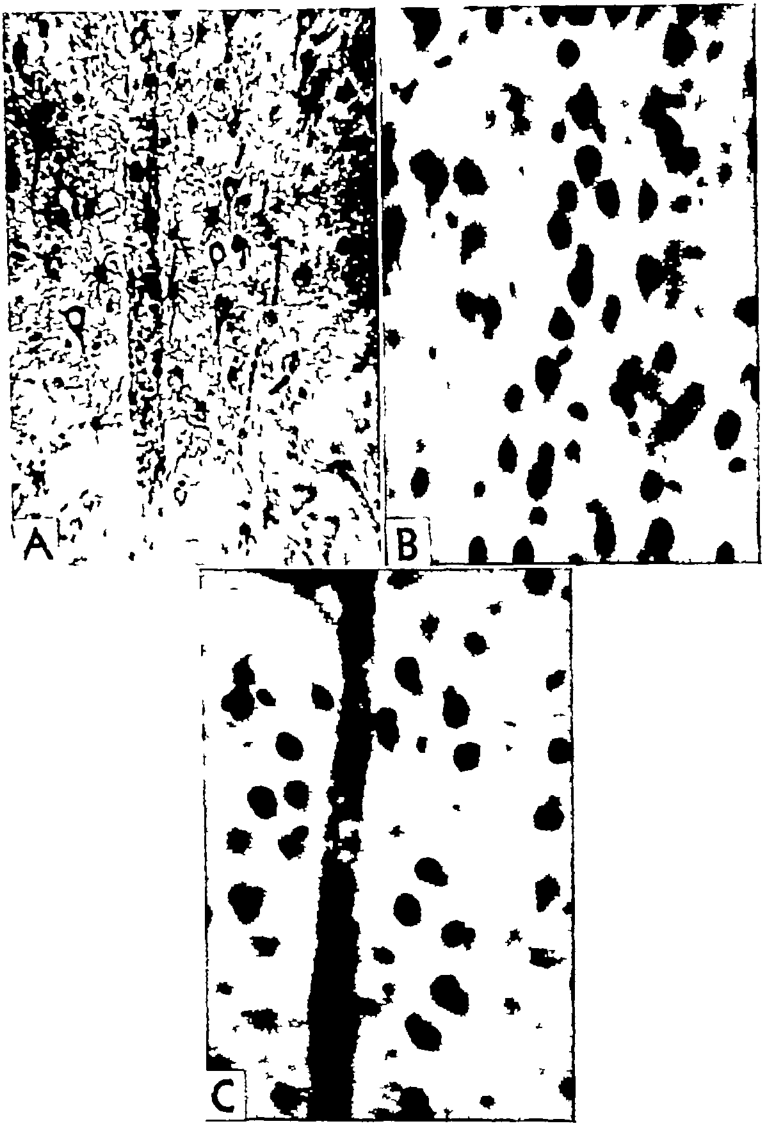

Fig 7

A—Section of the gyrus behind the pseudo-sylvian sulcus of control cat—145X.

B and C—Section of the gyrus behind the pseudo-sylvian sulcus of intoxicated cat—500X. (Del Rio-Hortega Method)

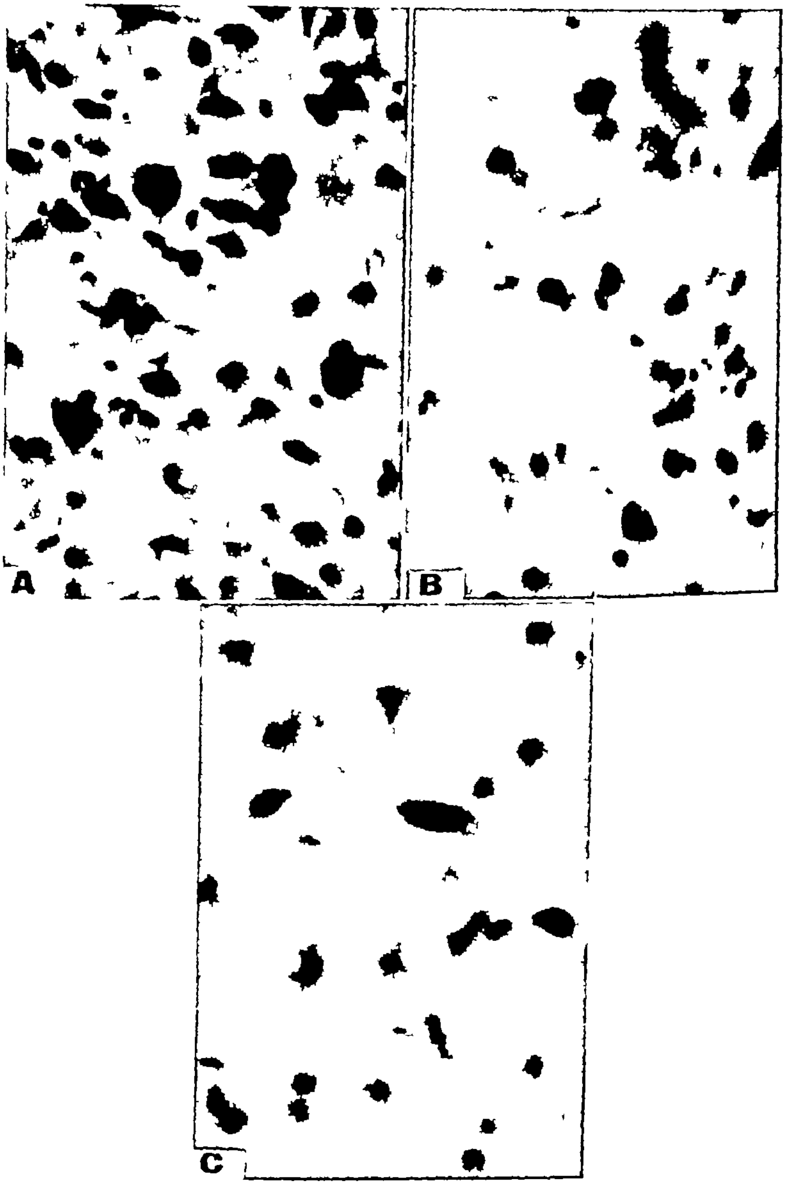

Fig 6

A—Section of central area of geniculate body of intoxicated cat—500X
B and C—Section of marginal area of geniculate body of intoxicated cat—500X. (Del Rio Hortega Method)

be detected only on the molecular stratum, even though not so evident as in the control cat

Spinal Cord, Brain Stem and Areas of the Cortex

Control Cat—Normal glial architectures

Intoxicated Cats—The spinal cord shows normal glial architecture, less evident glial architecture was found in the boundaries of the pons, in the brain stem as well as in other areas of the pons themselves, as much in the white substance as in the gray, sections of the frontal, parietal and occipital cortex showed no alteration of the glial structures

CONSIDERATIONS AND CONCLUSIONS

Objections could be made to this experiment on the basis of the known lability of the glial structures under silver impregnation Cerletti[19] in 1915 denied the existence of the glial processes That opinion was, however, due to the difficulty of impregnation of glial structures permitting the appearance of technical artifacts Different aspects of neuroglia observed under similar conditions have been reported by Cardona,[29] and Stigliani[27] assumed that the general conditions of the material would rule the glial demonstrability *Based on this assumption he explained the phenomenon of* glial phanerosis, which would not be hyperplasia, but only better identification due to self and surrounding conditions Doubtless this phenomenon is more evident in the cortex, and we found it in the gyrus behind the posterior ecto-sylvian sulcus giving the impression of gliosis On the other hand we found that in the gyrus behind the pseudo-sylvian sulcus the glial structure disappeared, leaving only the cellular bodies, many of which presented mitosis It seems evident that areas so closely placed and so deeply differentiated must be under different metabolic conditions This must also be the reason for the various observations of the neuroglia

We cannot say which is the true toxic action of the streptomycin over the neuroglia in the observed areas whether the alterations are definitive or transitory, or whether this toxicity acts on the neuroglia alone, but we can affirm the fact that this toxic action reaches the feeding elements cytes with small processes, several gliocytes without any processes Transitional elements were found here between protoplasmatic and fibrous processes (see Figs 5, 6)

Intoxicated Cats—Many atypical mitosis of the gliocytes, very few impregnated processes could be found

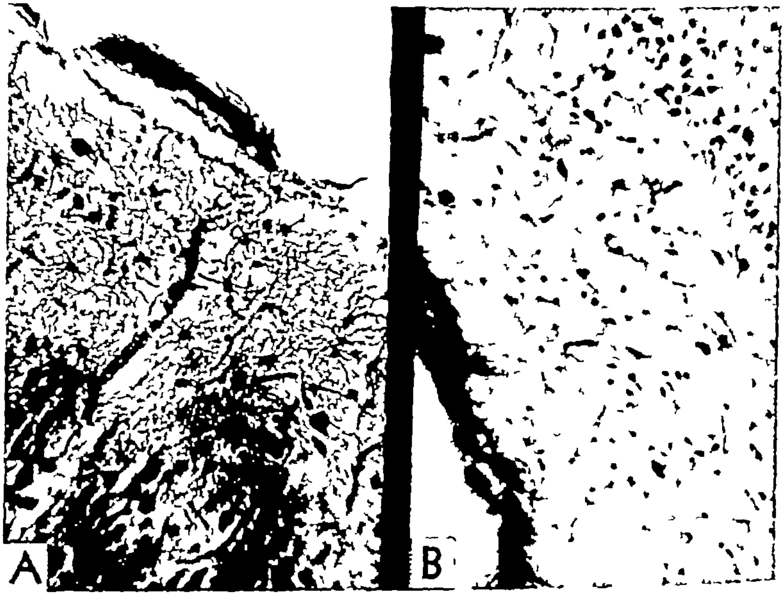

Fig 8

A—Section of molecular stratum of the gyrus behind the pseudo-sylvian sulcus of control cat—145X

B—Section of molecular stratum of the gyrus behind the pseudo-sylvian sulcus of intoxicated cat—80X. (Del Rio-Hortega Method)

Auditory Cortex

Control Cat—Glial architecture of the third type Fibrous and protoplasmatic astrocytes, many oligodendrogliocytes with cuboid body and smooth and hairlike processes (see Figs 7, 8)

Intoxicated Cats—Glial architecture too evident in the gyrus behind the posterior ecto-sylvian sulcus seeming a gliosis, while in the gyrus behind the pseudo-sylvian sulcus the gliocytes show no processes and some mitosis Processes could called phanerosys and glial-reaction expressed by intense mitotic activity, which is seen mainly in the geniculate body Glial phanerosys and mitosis are also visible in the girus behind the pseudo-sylvian sulcus, permitting the author to assume the hypothesis of this being the cortical center of the acoustic radation

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of the nerve cells, inducing glial mitosis with lack of impregnation of the glial processes

Our observations need further histological and cytochemical basis It is our intention to repeat the experiment and study the material with a polarizer microscope to observe eventual modifications of the refringency of the processes This, we understand, would give a better answer as to the destiny of the processes We also think it necessary to verify the number of glial nuclei statistically, and so prove the existence of hyperplasia, also, we wonder whether the processes would remain impregnated if submitted to more intensive fixation

With the data obtained in our experiment we can, however, conclude that the dihydro-streptomycin exerts toxic action on the centers of the cochlear pathway, as shown by atypical glial mitosis and disappearance of glial structures, well demonstrated in specimens taken from a control animal, treated with the same technical approach, furthermore, the presence of mitosis and the absence of glial processes in one area of the gyrus behind the pseudo-sylvian sulcus, permits us to assume that this is the site of central acoustic radiation in the cat

SUMMARY

Employing the silver impregnation method of Del Rio Hortega, the Mallory and the Iron-hematoxylin methods, the author studies the neuroglia of the nuclei of the cochlear pathway (ventral and dorsal cochlear nuclei, superior olive, trapezoid body nucleum and lateral lemniscus nucleum), the sub-cortical acoustic centers (tuberculum quadrigeminus inferior and medial geniculate body) and the cerebral cortex concerning the gyri in front of and behind the pseudo-sylvian sulcus, presumed area of representation of the acoustic radiation, in four cats, intoxicated with daily doses of 0 10 to 0 20 grams of dihydro-streptomycin, applied parenterally for 17 to 22 days One cat was used as control

The glial architecture was found disorganized in the nuclei of the cochlear pathway and in the sub-cortical centers The neuroglia cells appear with protoplasmatic processes not easily identifiable In some cases it is visible, the phenomenon so-

tion of the internal spiral with the intraganglionic spiral fibers, whose real origins are in the superior olivar peduncle, forming the so-called Rasmussen bundle[3,4] These fibers are directed to the internal acoustic cells which, therefore, receive double nerve supply, afferent and efferent

Rasmussen's description was confirmed by Fernandez[5], Portmann[6], Contu and Pirodda[7], and Fierre deBarros[8], while Bocca[9,10], Palumbi[11] and Del Bo and Livan[12,13], expressed the opinion that the spiral fibers were from sympathetic or vestibular origin, reminding us of the so-called cochleo-vestibular anastomosis, described by Boettcher,[14] Bovero,[15] Oorth,[16] Weston and Mesolella[17] Considering the external fibers, Held[18] and Kolmer[19] agree on their course and termination in the external acoustic cells

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Rasmussen's description was confirmed by Fernandez[5], Portmann[6], Contu and Pirodda[7], and Freire deBarros[8], while Bocca[9, 10], Palumbi[11] and Del Bó and Livan[12, 13], expressed the opinion that the spiral fibers were from sympathetic or vestibular origin, reminding us of the so-called cochleo-vestibular anastomosis, described by Boettcher,[14] Bovero,[15] Oorth,[16] Weston and Mesolella[17] Considering the external fibers, Held[18] and Kolmer[19] agree on their course and termination in the external acoustic cells

Very little emphasis has been placed upon the ganglion of Corti and with the exception of Fort,[20] the majority of writers place the ganglionic cells in the Rosenthal canal Writers limit themselves to the description of the cochlear nerve as a bundle of axons pertaining to the ganglion of Corti's bi-polar cells As a rule, neuroglia was found on its first segment, 6 to 8 mm from its apparent origin[21]

Many years ago, Hyrtl, Stannius, Kolliker and Pierret[22] found cells on the surface and interior of the acoustic nerve, and Erlisky[23] and Fort,[20] and recently Chiarugi,[24] described cellular elements in the vestibular branch of the VIIIth nerve, arranged in groups as in the principal ganglia

We used the cat as experimental animal, intravitally fixed with Rio Hortega's or De Castro's formulas The whole temporal bone was removed with the acoustic nerve up to the rhombencephalon Specimens were submitted to electrolytical decalcification and silver impregnated, by the Cajal De Castro, Bodian and Rio Hortega metohds Frozen sections were made from those under Cajal De Castro and Bodian impregnation, and colloidan-paraffin-fast inclusion permitted us to obtain a complete seriation from the cochlear to the rhombencephalon

We reached the following conclusions

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OBSERVATIONS AND CONSIDERATIONS ABOUT THE COCHLEAR INNERVATION OF THE CAT

PAOLO CONTU,

University of Recife, Brazil

Incomplete anatomical bases have been the cause of many hearing theories, therefore, problems concerning cochlear innervation are doubtless important

In our laboratory of Microscopic Anatomy we are considering the cochlear nerve problem, establishing systematic research under the most modern methods and techniques, and considering not only the organ of Corti but also the whole acoustic system

Careful revision of available literature demonstrates different distribution of peripheral cochlear nerve fibers among man and other mammals

Lorente de Nó's[1,2] classical division of nerve fibers in radial, external spiral, internal spiral and intraganglionic spiral fibers, was lately substantially modified by identifica-

3 The Rasmussen bundle is very evident on the base of the lamina espiralis, its fibers composing the internal spiral fibers, a continuation of the intraganglionic ones As previously demonstrated by Fernandez, they do not exclusively innervate the internal acoustic cells, but many turn backwards to the sustaining cells and from there are directed to the base of the limbus espiralis Portmann[25] already described nervous fibers of sensitive aspect in the limbus laminae espiralis

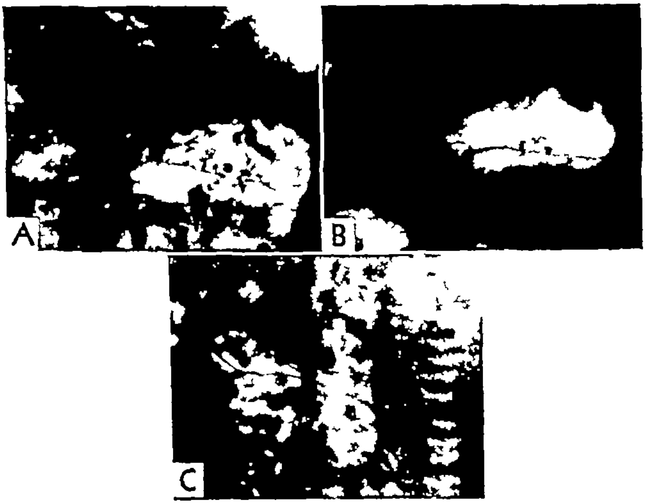

Fig 2

(A)—Medial fibers.

(B) and (C)—Basilar fibers passing through the gallery of Corti (Cajal-De Castro Method—Enl 500X)

4 Some of the spiral fibers of the gallery were found going to the apex, and some to the round window, as demonstrated by Fernandez In our specimens, compact groups of fibers coming out of the foramina were seen, penetrating radially the gallery of Corti, in whose center they were distributed brushlike Some of those fibers are directed to the external acoustic cells, whose nervous formations could not be followed Some branches were found reaching the sustaining cells and the sulcus laminae espiralis Held[18] attributes the innervation of the internal acoustic cells to these

5 With the Rio Hortega, in some celloidin sections we

1 Our findings confirm the majority of those previously reached, mainly those of Kolmer, on the nerve supply of the external acoustic cells The different fibers form the external spiral bundles of the 1st, 2nd, 3rd and 4th orders, progressively decreasing are the continuation of the radial fibers arising from the lamina espiralis, running radially to the gallery of Corti, and considering their particular topographical arrangement, would be better called "spiro-radial fibers"

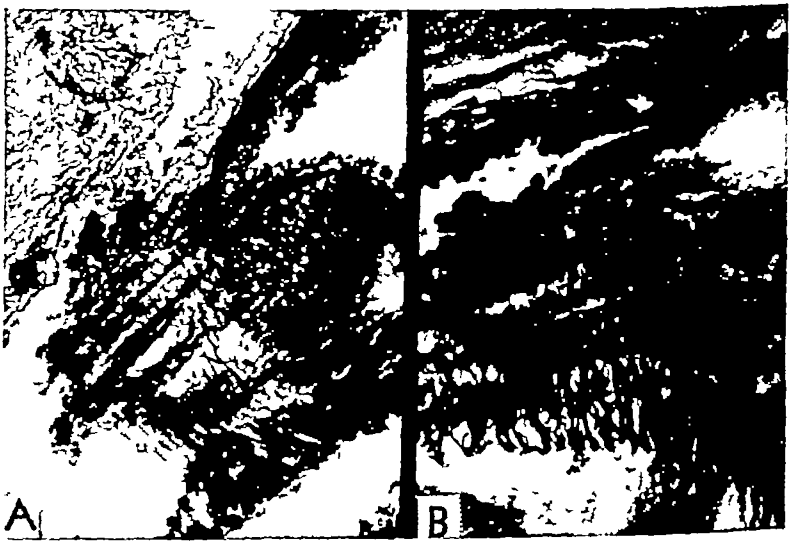

Fig 1

Section of the organ of Corti with the external spiral bundles (Cajal-De Castro Method—Enl 500×)

2 The fibers that come from the habenula go to the external acoustic cells through the gallery of Corti by the floor or the top, justifying the previous denomination of basilar and medial The basilar fibers reach the acoustic external cells, after passing through the Deiters cells, as well as the medial fibers This is clearly confirmed by Fernandez's topographical distribution of the medial and basilar fibers Both are found along the whole length of the gallery, but the medial fibers are found in greater number in the basal turn, and are gradually replaced by the basilar fibers that are frankly predominant in the apex found pyriform nerve cells of the pseudo-uni-polar type, on the vestibular wall, with one axon directed laterally to the base of attachment of the Reisner ligament and of the tectorial membrane, the other, to the sulcus and base of the limbus espiralis One isolated element of bi-polar type was also found

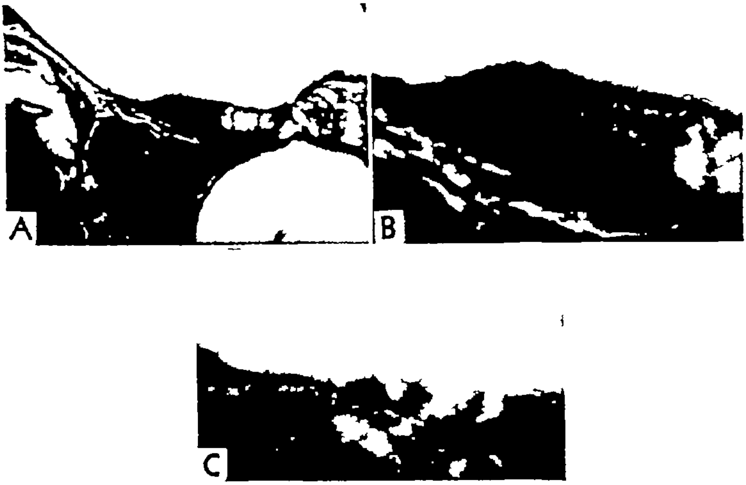

Fig 5

(A)—Vestibular wall of the Limbus Espiralis with pseudo-uni-polar cells (Del Rio Hortega Method—Enl 150X)

(B)—Idem

(C)—Vestibular wall of the Limbus Espiralis with bi-polar cells. (Del Rio Hortega Method—Enl 500X)

6 Partially confirming and completing Fort's previous description, we assumed in 1956[26] that the cells of the ganglion of Corti are not strictly localized in the Rosenthal's spiral canal There is a gradual diminishing of the cellular elements starting from the spiral canal to the axis of the modiolus The ganglionic cells do not remain in the Rosenthal canal, where they are grouped mainly in the medial and internal portion, but as a matter of fact, are seen along the descending canals of the modiolus, essentially in the proximal portion of each canal, and they should not be considered only similar to the cells at the ganglion of Corti but also as migrated cells, and therfore, as a part of it

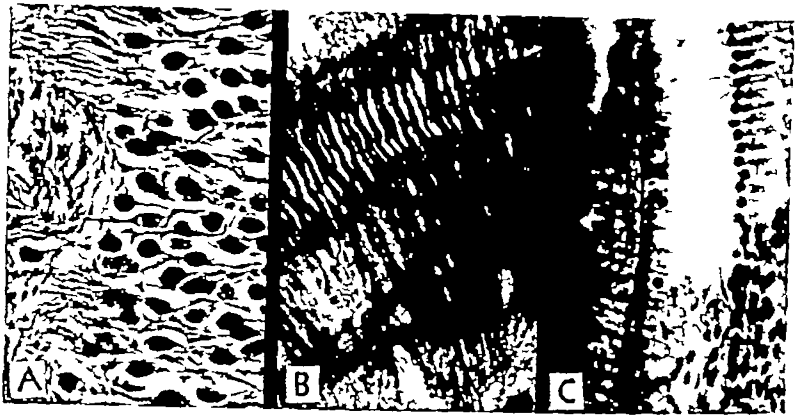

Fig 3

(A)—Spiral ganglion On the left transversally sectioned fibers of the Rasmussen spiral-bundle (Bodian Method—Enl 500X)

(B)—Bony Lamina Espiralis with spiral fibers (Cajal-De Castro Method—Enl 500X)

(C)—Base of internal acoustic cells showing double nerve supply (Bodian Method—Enl 500X)

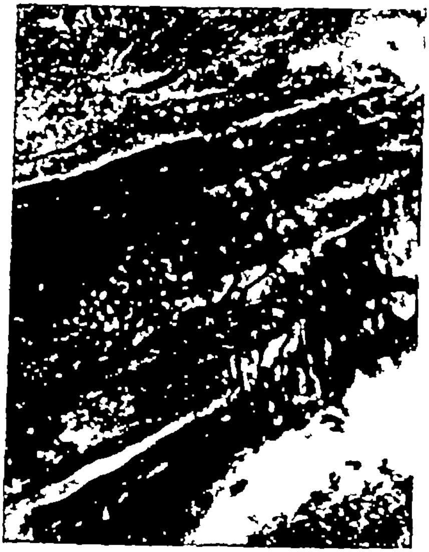

Fig 4

Spiral fibers of the gallery (Cajal-De Castro Method—Enl 500X)

7 In 1956[27-28] we reported the existence of multi-polar nerve cells in the cochlear branch of the acoustic nerve Probably those cells were an external projection of the primary acoustic nuclei

8 By the demonstration made, the complication of the cochlear innervation is evident The presence of pseudo unipolar type cells in the vestibular wall of the limbus espiralis, suggests the hypothesis of innervation of the tectorial membrane and, therefore, the possibility of closing a "neuronic arch" between that membrane and the hairs of the internal and external acoustic cells

SUMMARY

Studying the cochlear innervation of the cat, the author, employing the silver impregnation methods of Cajal De Castro and Rio Hortega, after electrolytical de-calcification, reached the following conclusions

a He agrees with Kolmer in the innervation of the external acoustic cells by external spiral bundles of first, second, third, and fourth orders, that by particular topographical disposition would be better called spiro-radial bundles

b The Rasmussen bundle is very evident, and some of its fibers turn backwards to the sustaining cells reaching the base of the limbus espiralis

c The spiral fibers on the organ of Corti are easily identified

d In the vestibular wall of the limbus espiralis were found pseudo-unipolar cells with fibers which were directed to the base of the limbus espiralis and on the other side to the tectorial membrane

e The cells of the ganglion of Corti did not remain circumscribed in the Rosenthal canal, but they were also found in the descending canals of the modiolus

f In the cochlear branch of the acoustic nerve were found multi-polar cells probably originating in the primary acoustic nuclei

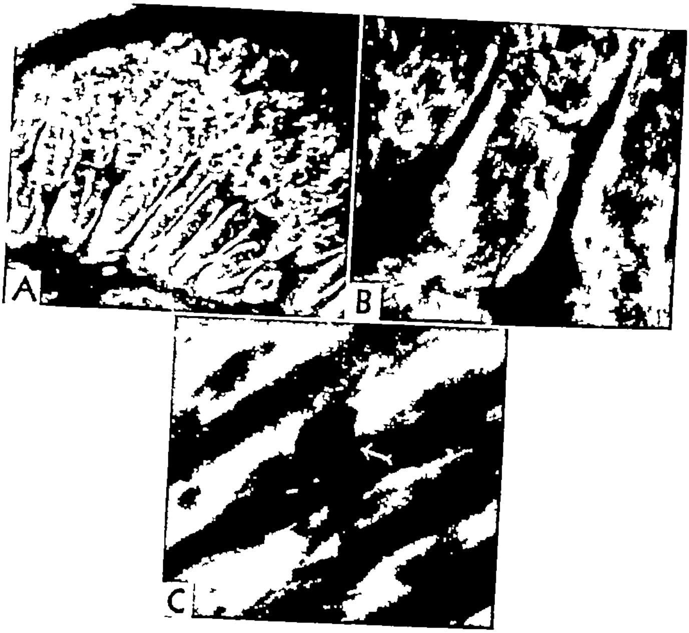

Fig 6

(A)—Rosenthal and descending modiolar canals (Cajal-De Castro Method—Enl 85X)

(B)—Bi-polar-cells in a descending modiolar canal (Cajal-De Castro Method—Enl 375X)

(C)—Bi-polar cells in a descending modiolar canal (Cajal-De Castro Method—Enl 850X)

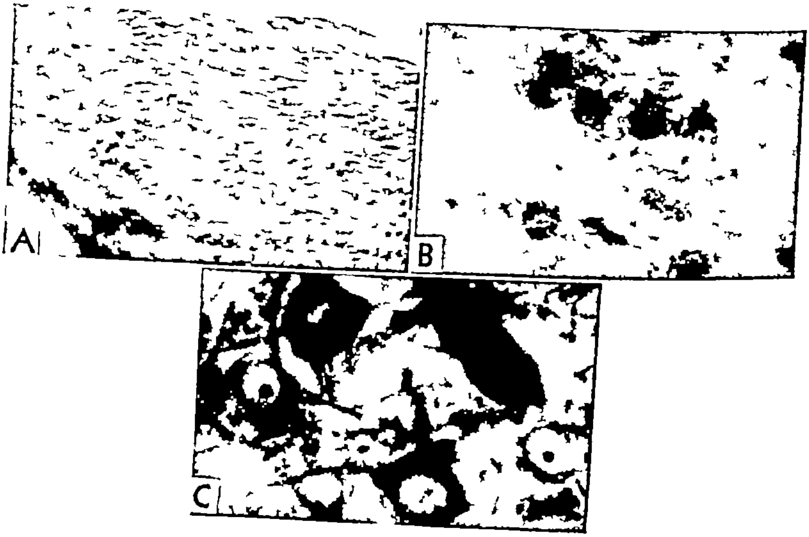

Fig 7

(A)—Acoustic nerve with multipolar cells (Enl 85X)
(B)—Idem —(Enl 375X)
(C)—Iden —(Enl 850X)

(Cajal-De Castro Method)

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DC POTENTIALS OF THE MEMBRANOUS LABYRINTH

(Abstract) *

CATHERINE A SMITH,
HALLOWELL DAVIS,
BRUCE H DEATHERAGE,
and
CARL F GESSERT,

Washington University, and Central Institute for the Deaf,
St Louis, Mo

The membranous labyrinth of the internal ear is a closed epithelial tube filled with endolymph and surrounded by perilymph It is divided into compartments by local constrictions and dilations The cochlear duct and the saccule are connected by a short narrow duct The latter is also separated from the utricle by another (indirect) tubule Previous analysis of endolymph has shown it to contain 144 m eq /1 of potassium and 16 m eq /1 of sodium, whereas perilymph shows the opposite potassium-sodium ratio (Smith, Lowry and Wu)

The DC potentials of the cochlear duct, utricle and saccule of the guinea pig were measured by means of a glass pipette-

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*The full paper will be published elsewhere.

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perilymph and surrounding tissues This DC endocochlear potential is thought[1,2] to contribute to the generation of the cochlear microphonic and to the associated electrical current flow that is believed to stimulate the nerve endings[4] The source of the DC potential is unknown The electrochemical mechanism seems to be rather specific and more closely dependent on oxidative processes than is the familiar negative intracellular polarization[4] The site of the generation had been tentatively located both in the hair cells and in the stria vascularis The present experiments were planned in the hope of deciding between hair cells and stria vascularis as the locus, by injuring the inner ear of guinea pigs in ways which could be more or less selective The experiments actually yielded important additional information concerning the source and significance of both the cochlear microphonic and the negative summating potential

As an agent to injure hair cells, streptomycin, injected locally into the bulla, was suggested to us by Dr Harold Schuknecht[11] He actually made the first three injections in the present series The procedure directed at the stria vascularis was extensive obstruction of the cochlear vein and some of its collaterals Kimura and Perlman have described the surgical procedure and the resulting pattern of histological changes in stria vascularis and in the sensory cells[7] The earliest changes apparently occur in the stria and the spiral ligament

We did obtain clear differential effects by these two methods In each case an interval of a few (four to seven) days proved best for obtaining the desired degree of change in electrical activity and in histological appearance

The electrical responses measured, as indices of the functional state of the organ of Corti, were the cochlear microphonic (CM), the negative summating potential (SP), and the action potential spike (AP) CM is known to depend upon the hair cells AP is generated by the nerve fibers in the modiolus and gives evidence of the integrity of the overall system of tectorial membrane, hair cell, nerve ending and nerve fiber SP, like CM, probably originates in hair cells, but the association has not been established clearly To draw electrode Endolymph was withdrawn in the same pipette for potassium analysis Successive measurements made on the same ear showed the potential of the cochlear duct to be +70 to +80 mv (as described by von Békésy), and that of the utricle, to be not more than +5 mv The saccular potential, measured in other animals, was similar to that of the utricle Endolymph from both utricle and cochlea had a high potassium content similar to that of the previous analysis The high positive potential is, therefore, restricted to the cochlea, whereas the high potassium content appears to be the same throughout the membranous labyrinth

MODIFICATION OF COCHLEAR POTENTIALS PRODUCED BY STREPTOMYCIN POISONING AND BY EXTENSIVE VENOUS OBSTRUCTION *†‡**

H Davis,
B H Deatherage,
B Rosenblut,
Central Institute for the Deaf,
St Louis, Mo
C Fernandez,
R Kimura,
University of Chicago,
Chicago, Ill ,
and
C A Smith,
Washington University,
St Louis, Mo

INTRODUCTION

The endolymph in scala media of the guinea pig cochlea shows a positive DC potential of about 80 mv relative to the collaterals was carried out by R. K. at the University of Chicago. The method, the resulting symptoms and the usual histological changes have been described elsewhere.[illegible] The animals were transported to St. Louis and tested at intervals ranging from five days to 28 days. The most satisfactory degrees of partial injury were found five to eight days postoperatively.

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**Assisted by U S Public Health Service Grant B-680

Both the streptomycin and the venous-congestion animals were prepared for final test by our usual methods.[13] Dial in urethane 0.5 cc. per kilo was given intraperitoneally. Rarely, a small supplementary dose was required. The treated cochlea was exposed by opening the bulla and two fine, enamel-insulated nichrome-steel wires ($25\ \mu$) were introduced through small holes drilled into scala vestibuli and scala tympani respectively 3 to 4 mm. from the round window. Between these electrodes a fenestra was made through the bony shell of the cochlea to expose the spiral ligament behind the stria vascularis. A chlorided silver electrode, wrapped in Ringer-soaked cotton to avoid direct contact with the body fluids, was inserted under the skin at the edge of the wound and, in most experiments, an ear speculum that fitted snugly the output tube of a calibrated sound source[3] was sewed tightly into the external auditory canal.

The first four streptomycin animals were simply placed at a standard distance in front of an open loud-speaker and tested qualitatively with 9000 c.p.s. tone bursts, but it was soon found that stronger acoustic stimuli were needed. The closed, calibrated system, capable of delivering over 135 db. SPL at the test frequency of 7000 c.p.s., was employed thereafter, and all sound pressure levels readings are corrected to a position just in front of the tympanic membrane.

As a standard acoustic stimulus we employed a 7000 c.p.s. tone-burst with a 1 msec. rise time and 1 msec. fall time. The sound level remained constant for 4 (or sometimes 6) msec. This interval was long enough to allow easy recognition of SP but too short for echoes in the acoustic system to confuse the pattern. The 1.0 msec. rise time is the slowest that we found consistent with the good synchronization of nerve impulses that is necessary for a sharp "N$_1$ spike."

firm conclusions, therefore, we seek primarily a relation between CM response and the positive DC resting potential of scala media under varying degrees of injury inflicted by the two different methods Secondly, we seek the relation between depression of electrical activity and any histological changes that can be demonstrated in particular types of cell Finally, the relationships among the various electric responses are of great interest in their own right, as they indicate possible mechanisms or functional relationships

METHODS

Streptomycin sulfate, in doses of 0 1 to 1 0 gm dissolved in distilled water, was injected into one bulla of each of 26 guinea pigs The volume of fluid injected was usually about 0 2 cc The hypodermic needle was at first forced through the wall of the bulla or through the tympanic membrane It proved more satisfactory, however, to expose the bone of the bulla in a preliminary operation and to drill one hole for the hypodermic needle and another to allow escape of air Even so, some fluid may have been lost through the Eustachian tube before the drug was entirely absorbed, so that the exact dosages were uncertain

A time interval of four to seven days between injection and test was convenient and sufficient Longer intervals increased the chances of complications, such as otitis media and formation of adhesions, and tended to give more injury to the cochlea than was desired

Practically all 22 of the animals successfully injected and carried to acute experiment, showed signs of unilateral vestibular deficit, such as nystagmus and a head posture with rotation around the long axis, during the first two days of the interval

At the final experiment the bulla usually contained some mucoid or serous blood-stained fluid, and the mucosa was often thickened and vascularized, but the tympanic membrane was intact and, after the bulla had been swabbed out, the ossicles were usually freely movable

Surgical obstruction of the cochlear vein and some of its chanical stiffness, and ability to penetrate spiral ligament and structures beneath it without undue injury Details of the construction of the pipette-electrode, its carrier and the associated DC amplifier are given elsewhere[12] Measurements were made on the face of an oscilloscope with the help of an internally illuminated lucite scale A moving-film record of the movements of the oscilloscope spot during insertion and withdrawal of the pipette was made as routine but was actually used only to resolve doubts as to direct scale readings when the changes were unusually complicated or rapid The silver electrodes were freshly chlorided each day

Just before penetration the amplifier was always balanced to give zero reading while the tip of the pipette was immersed in the film of fluid over the spiral ligament A zero reading was also taken again after withdrawal but just before breaking contact This final reading usually agreed within ± 1 mv with the original The pipette was advanced by steps until further advance gave no further increase in DC potential In a few cases the last advance caused a fall in the measured potential, presumably due to penetration of Reissner's membrane Only rarely did we fail to encounter a region of strong positive DC potential on the first attempt Always when the maximum was less than +30 mv and sometimes, as a control, in other experiments a second and even a third penetration was made in a slightly different position or direction Actually, if a potential over 30 mv had been encountered on the first trial no higher potential was found on any later trial, and usually the voltage was the same or a few millivolts less

As control values for DC measurements made in the basal turn by the above method we employed nine initial measurements made in another series of experiments that involved subsequent chemical injections into scala media or scala tympani[5] These experiments overlapped the present series in time

Normal thresholds and input-output curves were determined in a series of 16 experiments that will be described in detail elsewhere The procedures were identical with those of the

Complete input-output functions for cochlear microphonics, action potential and negative summating potential were plotted from measurements made of standing wave patterns on the face of the oscilloscope The results are expressed as microvolts DC displacement from the resting baseline for the summating potential, as microvolts peak-to-peak for the cochlear microphonic and as microvolts relative to the baseline of the first wave (N_1) in the action potential response CM and SP were both measured as voltage difference between scala vestibuli and scala tympani AP was recorded between the null point (for CM) on a resistance connected between the scala vestibuli and the scala tympani electrodes and the neck electrode Adjustment of the variable resistances in the network effectively eliminated CM potentials from the AP trace and vice versa[13]

With these electrode positions the AP is recorded as the impulses enter the internal auditory meatus, and the spike represents the impulses in *all* fibers that are activated within the first millisecond, regardless of the point of origin in the cochlea The CM and SP responses and the resting DC polarization, however, are chiefly those generated within one or two mm of the position of the electrodes The contribution from distant points falls off rapidly with the distance[13, 14] The attenuation of CM with distance may be even more rapid than for the DC potentials because of capacitative conduction across the walls of the scala media The locus of maximal amplitude of displacement of the cochlear partition at 7000 c p s is only slightly apical from the position of the recording electrodes[12, 13] so both CM and SP are recorded efficiently

After recording the input-output data, we measured the DC potential of the interior of scala media relative to the outer surface of the spiral ligament The head of the animal had been clamped firmly in a standardized position A micropipette electrode was now advanced into the scala media by means of a micro-manipulator Visual control was maintained through a binocular dissecting microscope (20×) Pipettes about 15 μ outside diameter filled with 0 85 per cent Na Cl solution gave a good compromise among the factors of simplicity of preparation, low enough ohmic resistance, me-generated within one or at the most a very few millimeters The condition of structures three to four mm from the round window is critical, while the condition of cells in the apical turns is irrelevant for the interpretation of our electrical tests except for the action potentials produced by "remote response"[6] The histological findings and also the results of our electrical measurements are summarized in Table I

In the streptomycin series, the mildest degree of injury to the hair cells was a slight pyknosis and shrinkage of the external hair cells in the lower half of the basal turn All but one of these ears, however, showed complete loss of the external hair cells up to, or nearly up to, the position of the recording electrodes The inner hair cells near the electrodes were sometimes present and apparently normal in appearance (see Fig 1) In other cases the nuclei were pyknotic and frequently displaced, and, in the most severely injured ears, the internal hair cells as well as the external hair cells (see Fig 2), and sometimes the supporting structures also, disappeared entirely

The changes in the stria vascularis were much less than those in the organ of Corti The most severe change was a shrinkage of cells with some edema appearing between or behind them (see Fig 3) There was no general cellular degeneration

Changes in the stria and also changes in the hair cells were not necessarily continuously graded but might vary irregularly from section to section Whereas all of the ears in the series showed definite changes in the external hair cells, only six showed recognizable changes in stria vascularis, and only one of these showed injury in the stria that extended throughout the length of the cochlea

In the seven most severely poisoned ears the supporting cells of the organ of Corti had also degenerated Sometimes they still formed a continuous layer (1072, 1078, 1090, 1108) but in others there were bare patches on the basilar membrane (1073, 1089) In the most advanced cases (1071, 1089) replacement of the degenerated supporting cells by squamous epithelium had begun but was not yet complete In the present series except that no fenestra was made in the basal turn, and sometimes a second pair of recording electrodes was placed in the third turn

At the end of the acoustical and electrical tests the animals were perfused with isotonic sodium chloride solution introduced into the aorta After exsanguination the animal was perfused with Heidenhain-Susa solution and the head or the temporal bones prepared for histological study by routine methods The heads of the animals with venous obstruction, studied by C F at the University of Chicago, were sectioned as a whole through both cochleas symmetrically [7] This method of cutting requires careful orientation in the microtome to obtain mid-modiolar sections of both cochleas at once, but allows close immediate comparison between the operated and the opposite normal ear

RESULTS HISTOLOGICAL

Streptomycin

The injurious effects of streptomycin varied according to the dosage employed, the number of days elapsed following the dosage, the type of tissue, and the distance from the round window The relationships of injury to size of dose and to duration following the injection were not examined closely because it was obvious that only slight correlations exist within the range of dosage represented in our experiments The external hair cells are the most vulnerable cells The supporting structures of the organ of Corti and the internal hair cells are fairly vulnerable, the stria vascularis is affected only slightly, and Reissner's membrane, the basilar membrane, sulcus cells and limbus are very slightly affected, if at all A gradation of effect away from the round window is very clear and seems to establish beyond doubt the route of entrance of the streptomycin, namely through the round window membrane

The ears studied in this series were examined both with relation to the extent lengthwise of the injury and to the severity of injury in the region of the fenestra As noted above, our electrode system is sensitive to CM, SP and DC severely affected ears some degeneration appeared in the limbus also, and the internal and external spiral sulcus cells were lost

In one ear (1125) the cochlear duct was collapsed and Reissner's membrane lay closely against the stria vascularis over the greater part, although not quite all, of its width All of the vestibular membranous labyrinth was likewise collapsed in this ear, even the semicircular canals

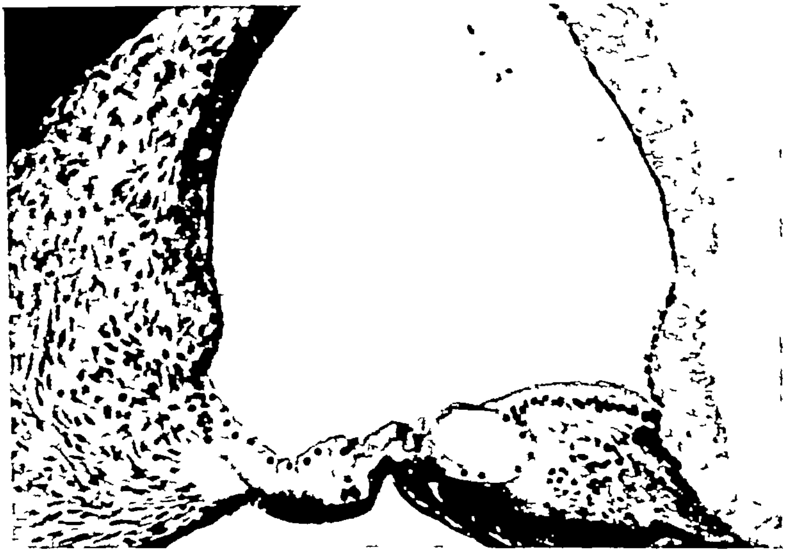

Fig 1. Degeneration of external hair cells in streptomycin poisoning Internal hair cell present in fair condition. Stria vascularis is normal DC potential —81 mv See Fig 10 for input-output curves (Guinea pig 1097)

In some preparations Reissner's membrane bulged somewhat into stria vascularis, either locally or throughout the cochlea, but we attribute this bulging to artifacts of fixation

With the exception of animal 1107 no neural injury was observed, either to the nerve fibers or to the ganglion cells, unless the animal had survived at least six days after the injection After the sixth day the amount and severity of injury to nerve tissues seems to correlate quite directly with

GUINEA PIG NUMBER	TREATMENT			HISTOLOGICAL IN BASAL TURN NEAR ELECTRODES			RESTING DC		ELECTRICAL RESPONSES TO 7000 CPS BURSTS									GUINEA PIG
				STRIA VASCULARIS	HAIR CELLS INTERNAL	HAIR CELLS EXTERNAL			CM DB - SPL Thresh	CM DB - SPL Break	CM DB - SPL Max	CM µV Max.	SP DB at 8µV	SP µV 110db	AP DB Thresh	AP µV at 57db	AP µV at 110db	
								MV										
NORMAL MEDIANS							N 9	77	35	76	103	800	63	500	26	100	400	
STREPTOMYCIN									FIELD STIMULATION									
	DAYS	GM.																
1071	12	.12		1 Slight local changes	ABSENT in all turns	ABSENT		5 to 10	No responses to 9000 cps bursts at about 100 db									1071
1072	12	.08		NORMAL	Mostly ABSENT	ABSENT		90 to 95										1072
1073	7	16		1 Moderate local changes	Entire ORGAN of CORTI	ABSENT in all turns		< 4										1073
1078	7	.07		2 Moderate injury	ABSENT	ABSENT		95										1078
1088	8	.20		1 Very slight changes	ABSENT in all turns	ABSENT		5										1088
									CLOSED ACOUSTIC SYSTEM									
1079	7	07		▲ NORMAL	Minimal injury	pyknotic and shrunk		87			105		present		good response			1079
1090	6	06		NORMAL	FAIR	ABSENT transition zone		77			very small		present		present			1090
1096	4	08		NORMAL	ABSENT in all turns	ABSENT		60	113		?	2	Not seen at 110 db					1096
1097	4	10		NORMAL	FAIR	ABSENT transition †		81	78	99	107	38	78	256	64	0	152	1097
1099	4	.04	Conductive*: 7db	Specimen damaged in preparation				89	49	88	106	264	62	260	38	34	256	1099
1101	3	.04		NORMAL	FAIR	ABSENT below GOOD above		79	38	70	95	280	51	320	32	36	138	1101
1107	4	05		2 Widespread but mild	Shrunk	ABSENT transition		58	64	86	102	60	75	208	69	0	190	1107
1108	4	.05		NORMAL	ABSENT (pyknotic in Turn II)	ABSENT		73	120			1	absent at 110 db		85 remote AP 54			1108
1109	4	.05		NORMAL	NORMAL	ABSENT, but fair in Turn II		72	70	85	105	44	74	160	79	0	60	1109
1110	4	.07		NORMAL	NORMAL	Transition		87	50	?	105	120	59	200	38	54	250	1110
1111	4	.06		NORMAL	Shrunk	Pyknotic ?		62	43	72	97	210	58	440	38	56	190	1111
1112	4	.08		NORMAL	NORMAL‡	Transition		73	40	68	85	144	50	440	30	114	260	1112
1113	6	.07		NORMAL	NORMAL	Transition		93	51	74	110	174	58	432	45	36	268	1113
1114	5	.07		NORMAL	FAIR	ABSENT transition above		88	44	75	95	268	48	500	34	60	240	1114
1123	6	10	Otitis Media	NORMAL	GOOD	ABSENT		86	Very small responses ; also conductive loss									1123
1124	6	13		NORMAL	Slightly shrunk	ABSENT transition nearby		78	71	85	107	65	79	180	79	C	114	1124
1125	6	20		1 NORMAL	ABSENT in all turns	ABSENT		71	No responses of any kind at 130 db									1125
VENOUS OBSTRUCTION							DB RE 77 µV	MV										
1103	7			4 Severe DEGENERATION	NORMAL	Severe DEGENERATION	6.8	36	65	no	107	12	76	64	47	24	240	1103
1104	8		Otitis Media 15db	3 Moderate DEGEN.	NORMAL	Mild Degeneration	3.2	53	71	85	95	18	69	100	66	0	150	1104
1115	28			3 Partial ATROPHY	NORMAL	NORMAL	0.8	70	35	70	87	340	55	540	22	144	400	1115
1116	6			4 Transition to Degenerate	NORMAL	NORMAL	5.3	42	36	72	95	340	62	250	53	16	186	1116
1117	26			NORMAL	NORMAL	NORMAL	08	70	28	71	98	780	53	420	16	118	540	1117
1118	22		Otitis Media* 15db	NORMAL	NORMAL	NORMAL	-11	68	33	7	105	640	60	000	31	70	600	1118
1119	8			1 Worse above and below	NORMAL	NORMAL	6.6	36	42	76	101	360	68	208	40	56	380	1119
1120	5			[illegible] ATROPHY NECROSIS	NORMAL	Very few r ma	14.2	15	13	not seen		< 3	no	0	105 remote AP 6			1120
1121	[illegible]			5 DEGEN 1mm below	NORMAL	NORMAL	13.1	17	51	71	97	88	78	134	66	0	112	1121
1126	15			31 Spotty DEGENERATION	NORMAL	NORMAL	1.4	65	32	72	96	660	-0	840	20	140	520	1126

TABLE I

Δ The numbers in this column indicate degrees of abnormality of stria vascularis No entry = normal 5 = complete degeneration Details in text

* This correction has been applied in deriving the values of electrical data that are printed in small figures

o Reissner's membrane has collapsed over parts of the stria vascularis but elsewhere it is normal

† In this and other transition zones the external hair cells are absent below and present but not entirely normal above the electrodes

‡ The organ of Corti has collapsed in this preparation but this is probably an artifact

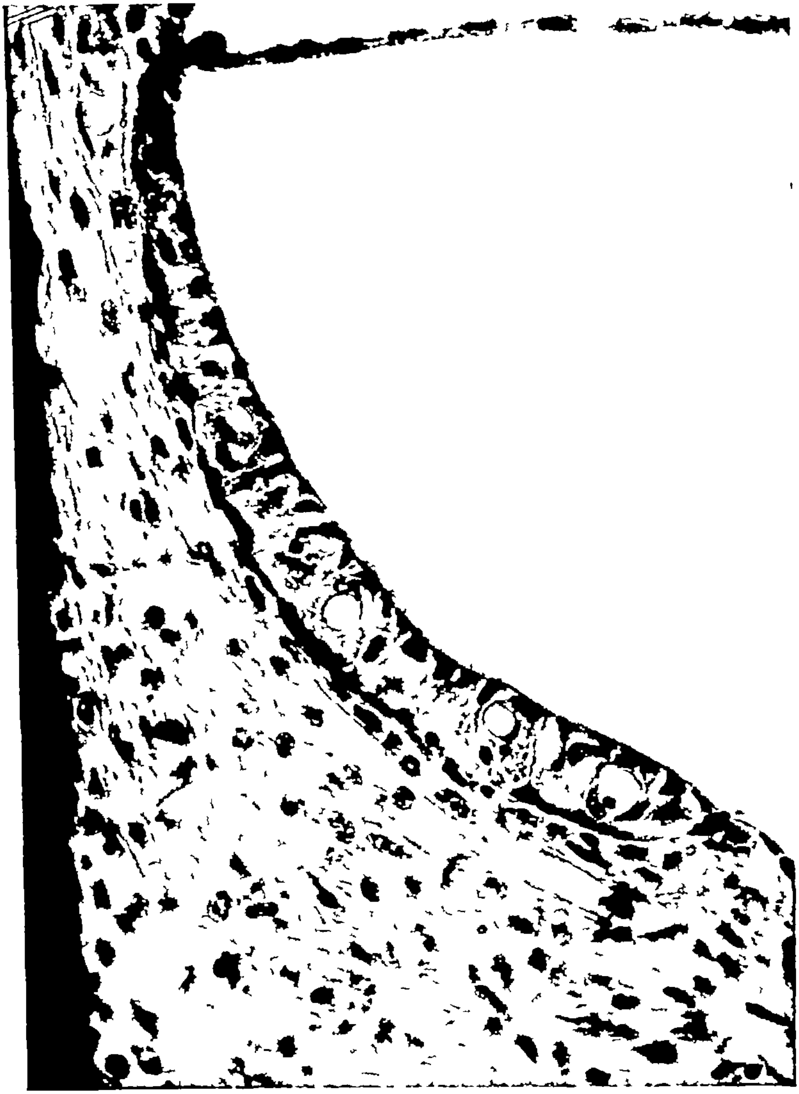

Fig 3 Mild injury of stria vascularis in streptomycin poisoning the most severe in the entire series DC potential +58 mv (Guinea pig 1107)

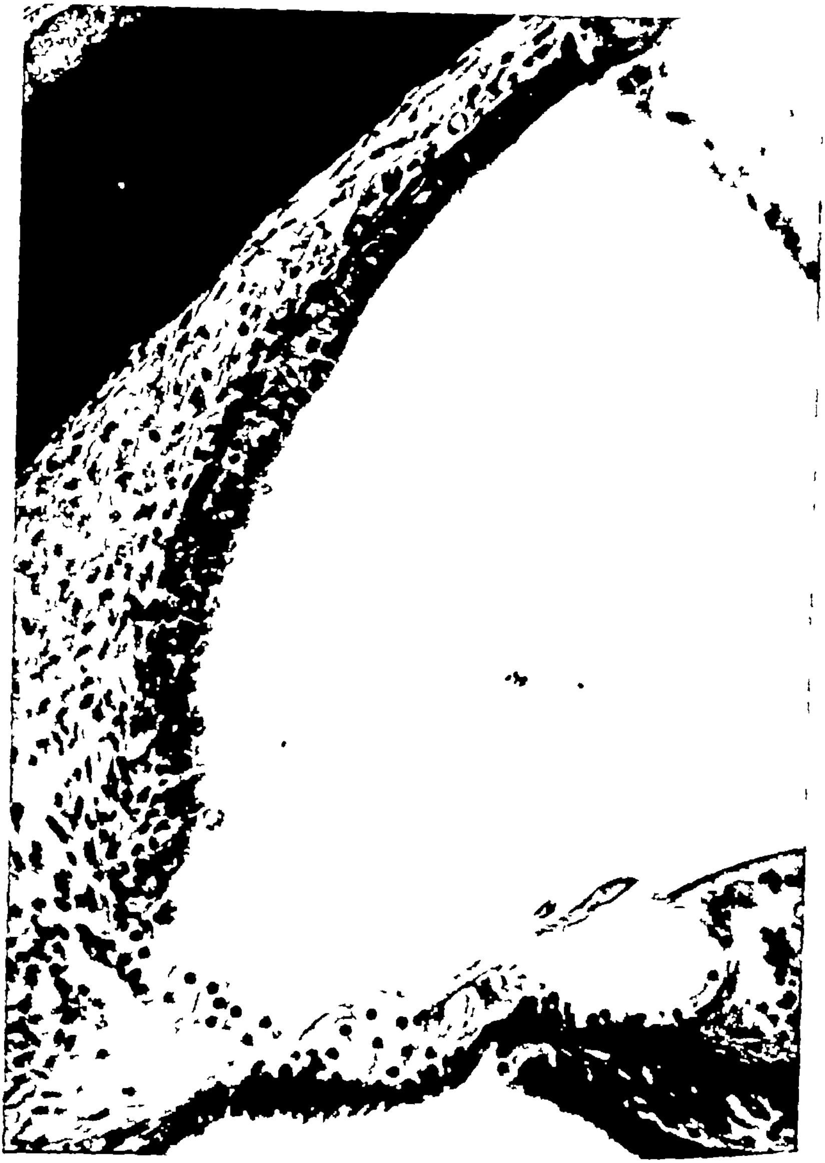

Fig 2 Degeneration of both external and internal hair cells in streptomycin poisoning Supporting cells present but abnormal Stria vascularis is normal Folding of basilar membrane is a fixation artifact DC potential +73 mv See Fig 12 for input-output curves (Guinea pig 1108)

3 Atrophy of some cells but not more than 50 per cent

4 More than 50 per cent of cells atrophic, usually accompanied by necrosis

5 Almost complete necrosis (Complete necrosis of stria vascularis was not seen in this series)

Grades 1 and 2 are characteristic of the streptomycin series The changes occurred usually near Reissner's membrane or the spiral prominence where a few cells might be degenerated or sloughed off These degrees of injury appear compatible with normal function Grades 4 and 5 were seen only in the venous obstruction animals, in six of which the stria vascularis was injured more severely than in any streptomycin animal With such injuries normal function would be very improbable or impossible The atrophy, when present, tended to be localized near the round window while the necrosis was usually quite extensive In Table I the numbers indicate the degree of injury at the position of the electrodes

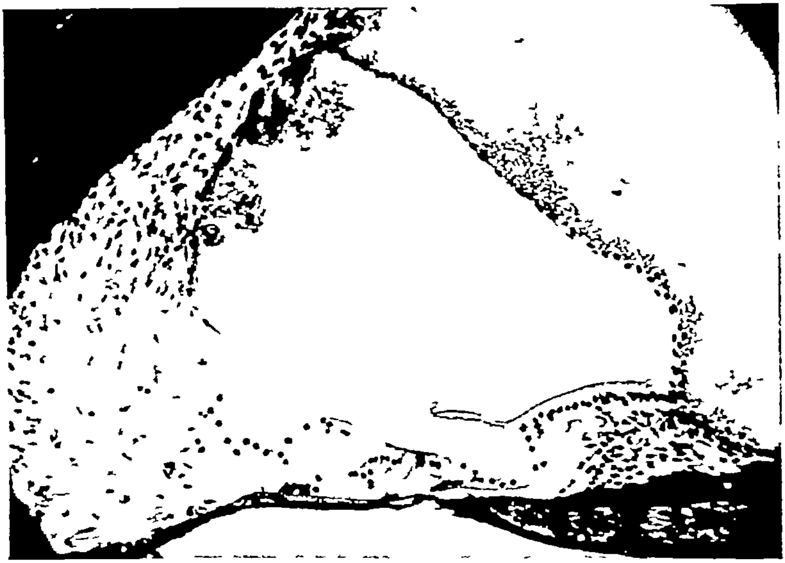

Fig 4 Degeneration of stria vascularis Grade 5 with normal hair cells and other structures of the organ of Corti DC potential +17 mv See Fig 9 for input-output curves (Guinea pig 1121)

the amount of injury to the hair cells It seems reasonable to suppose, therefore, that the injury to nerve tissues is not primary but is secondary to degeneration of the hair cells

Extensive Venous Obstruction

Satisfactory histological preparations were made of the cochleas with extensive chronic venous obstruction In general the effects were more severe in the animals studied within eight days following the operation Recovery apparently occurred after establishment of collateral circulation unless, as in some cases not studied electrically, part of the cochlea degenerated completely

The histological changes were always most severe in the immediate neighborhood of the round window The apical turns appeared quite normal and, just as with the streptomycin poisoning, the electrodes in several cases were placed in or very close to a zone of rapid transition from "nearly normal" to "clearly abnormal" tissues Unfortunately, this gradation of injury makes inferences as to the relation of electrical potentials to particular structures less secure than we had hoped

The tissue most severely affected by venous obstruction was the stria vascularis Next in order came external hair cells, the spiral ligament, and the supporting structures of the organ of Corti Slight hemorrhages into the perilymphatic spaces were frequent Other tissues were not affected

The obvious changes in the stria vascularis were *a* atrophy of the epithelium from the normal pseudostratified columnar to a simple cuboidal epithelium, *b* thrombosis or absence of the blood vessels, and *c* sometimes a detachment of whole cells or extrusion of pigment granules (see Figs 4, 5)

In Table I the degree of injury to the stria vascularis is coded as follows

1 Some slight changes in a few cells

2 Most cells shrunken with some edema between or behind them, but no general cellular degeneration

With venous obstruction the changes in the hair cells were pyknosis or total absence of nuclei. In the spiral ligament nuclei were sometimes missing, and scattered macrophages appeared. All of these changes and their distribution are similar to those already described elsewhere.

In one ear (1116) with normal hair cells and only local degeneration of stria vascularis near the round window, Reissner's membrane was partially collapsed. In another, with normal hair cells and a local region of mild degeneration of the stria, Reissner's membrane was torn from round window to the third turn. The electrical responses of this cochlea were emphatically normal (1117) and the damage is interpreted as an artifact. There were no other suggestions of abnormalities of hydrostatic pressure.

The cochlear aqueduct was not normally entered during the operation producing obstruction of the cochlear vein, but histological examination showed that it had been blocked in five experiments (1103, 1104, 1115, 1118 and 1119). In none of these, however, was there any abnormality of structure or electrical response that could be attributed to the blockage. Animals 1115 and 1118, with survivals of four and three weeks, showed blockage of the aqueduct with new bone formation but they also had normal histology and electric responses. This is clear evidence that the cochlear aqueduct is "dispensable" in the guinea pig.

RESULTS AND INFERENCES: ELECTRICAL

Endocochlear DC Potential

The endocochlear DC potential of nine normal controls ranged from +64 to +90 mv. The mean, the median and the mode of this group were all +77 mv. The distribution was normal in form as far as one can tell with such a small sample.

The ears injected with streptomycin divided clearly into two groups. In three animals (1071, 1073 and 1089) the endocochlear potential was 10 mv or less. From none of these three ears was any electrical response (CM, SP or AP) obtained with 9000 c.p.s. tone bursts at 65 db above the

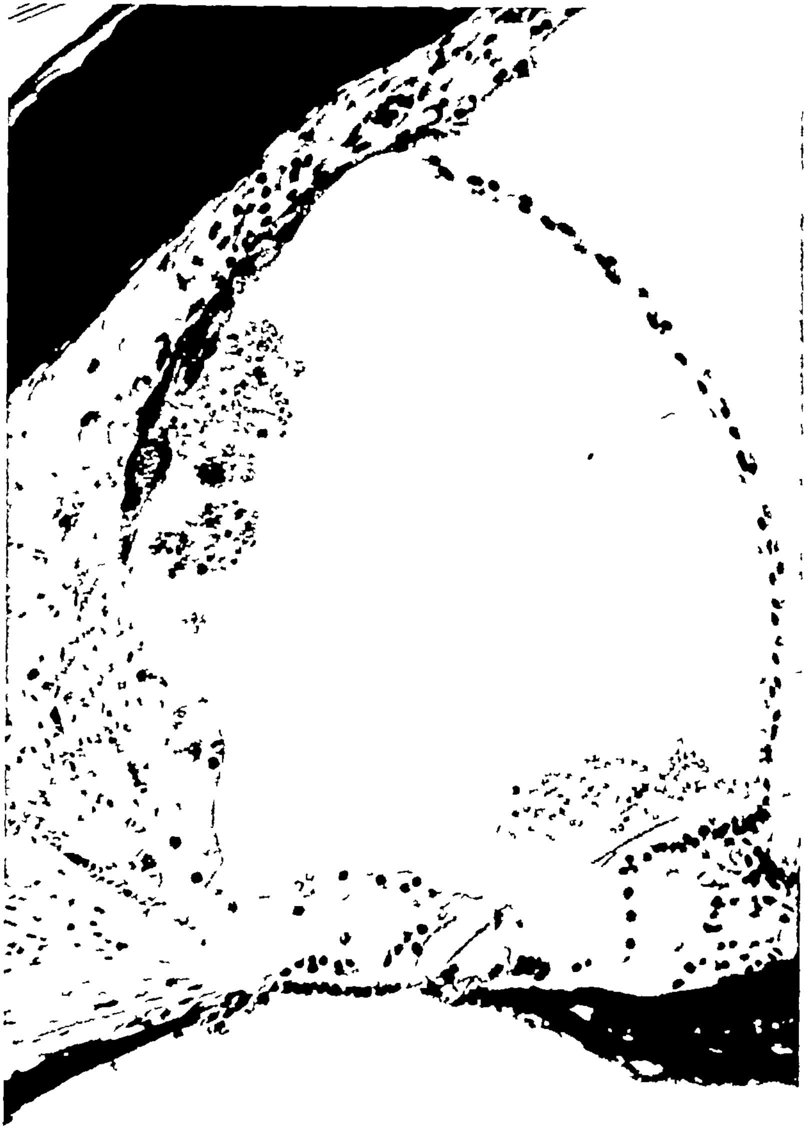

Fig 5 Atrophy and necrosis of stria vascularis Grade 5 Internal hair cells present External hair cells mostly absent DC potential +15 mv (Guinea pig 1120)

the lowest DC potential in the streptomycin series (+58 mv) showed the most definite and widespread injury in the stria vascularis (see Fig 3) The injury was not severe, however, in comparison with those produced by venous congestion

The other ears showed normal DC potentials with varying degrees of elevation of their CM "threshold"

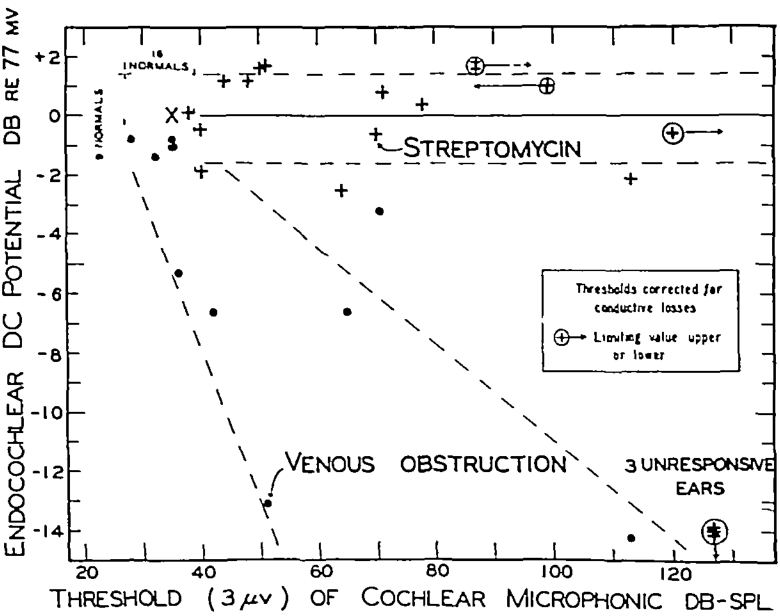

Fig 6 Distribution of endocochlear potentials with respect to cochlear microphonics. The large X indicates the median values of two groups of normal ears

Obviously, the DC potential can exist quite independently of the external hair cells and the CM response, but a normal or nearly normal stria vascularis is always present

The ten ears in which venous obstruction was produced divide into three groups with respect to their DC potentials Four were within normal limits, although all ten were below the control median Two (1120 and 1121) were greatly depressed, while the other four showed intermediate, moderately depressed potentials The four best ears had all been obnormal threshold. In all three the hair cells were absent in all turns, and the entire organ of Corti showed severe degeneration in the first turn. In 1073 and 1089 there were bare patches of basilar membrane, and in 1071 a very thin squamous epithelium had almost, but not entirely, replaced it. The stria vascularis, however, showed only the mildest degree of abnormality in patches here and there.

These three ears do not help to identify the generator of the DC potential. The potential may have been low because the generator in the organ of Corti was destroyed, or else because an intact generator in stria vascularis was short-circuited by a low-resistance pathway through denuded or incompletely covered basilar membrane. The basilar membrane and the mesothelial cells on its tympanic surface alone do not seriously obstruct the movement of ions.[14] The electrical barrier is the organ of Corti, the cells of Claudius and the sulcus cells.[12]

The other 19 streptomycin-treated ears are more decisive. All showed normal or nearly normal endocochlear DC potentials. Only three, at +58, +60 and +62 mv., lay below +64 mv., the lowest of our nine controls. Four showed potentials higher than +90 mv., the highest control. The entire distribution is shown graphically in Fig. 6. Here the abscissa is the "threshold" of the cochlear microphonic response. We shall see below that the voltage of the microphonic correlates very closely with the degree of injury to the external hair cells.

In 1108 a questionable CM response was seen, but only at 129 db SPL. All hair cells, external and internal, were absent in Turn I, but DC was +73 mv. Stria vascularis was normal. In 1096 a doubtful CM appeared at 113 db SPL. All hair cells were missing in all turns but the DC was +60 mv. Again stria vascularis was normal. The two ears (1072, 1078) that showed the highest DC potentials, +92 and +95 mv., gave no CM, SP or AP at 100 db SPL (9000 c.p.s. burst). The hair cells were nearly or completely absent in Turn I in both ears. Stria vascularis was entirely normal in 1072 and nearly so in 1078. On the other hand the ear (1107) with

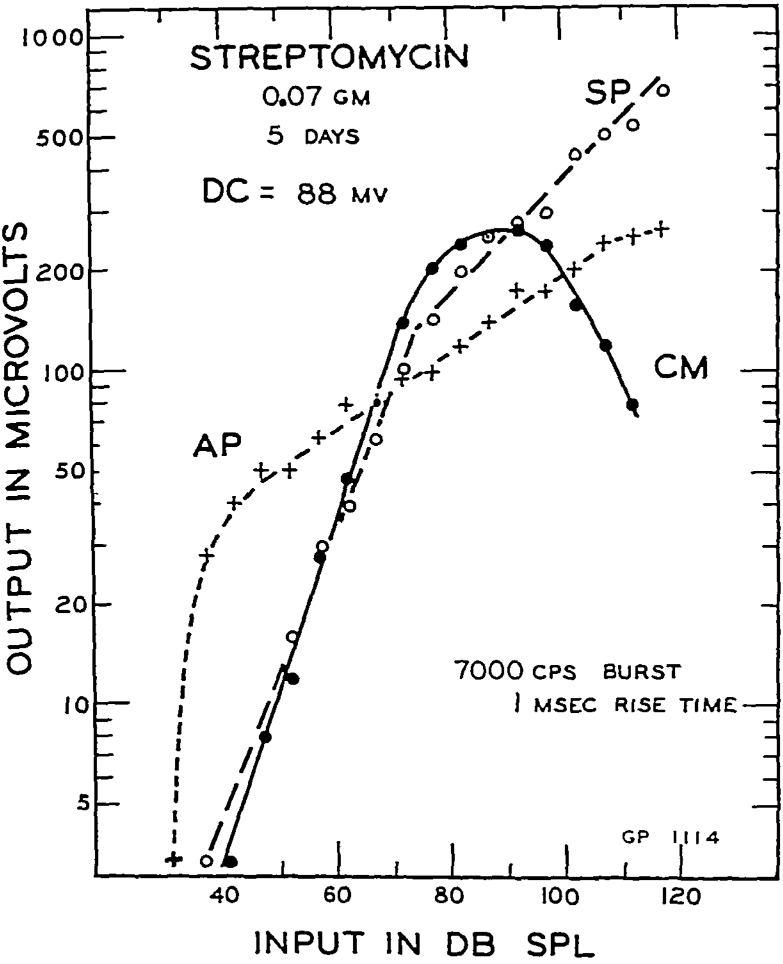

Fig 8 Normal AP and nearly normal SP input-output curves with slightly depressed CM from an ear poisoned with streptomycin. DC potential is normal

as well as the endocochlear DC potential were very greatly reduced The latter was only +15 mv The internal hair cells were apparently normal The external hair cells were missing, and the stria was atrophic above and necrotic below the position of the electrodes

The other depressed ear (1121) showed nearly normal hair cells, but a severe degeneration of stria vascularis from the

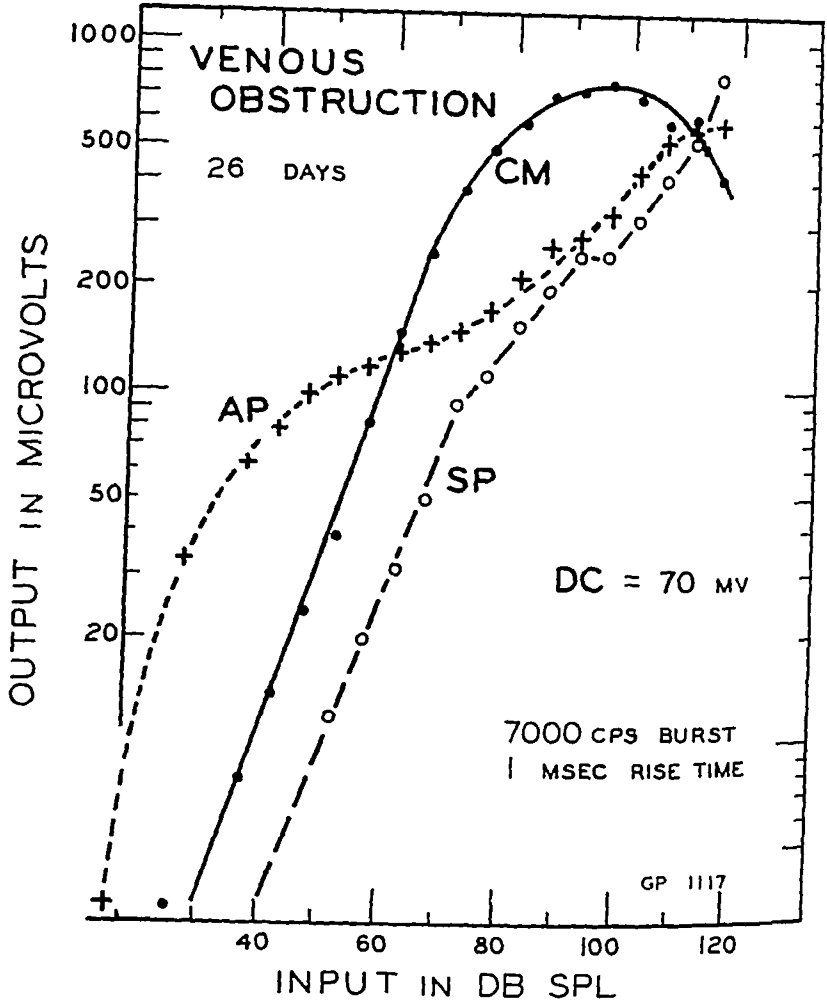

Fig 7 In this and subsequent graphs of input-output functions the threshold response plotted at $3\mu v$ has sometimes been interpolated or extrapolated In Table I however the threshold is the threshold of recognition of the response on the oscilloscope and sometimes differs slightly from the plotted value Stimulus 7000 c p s tone burst with 1 msec rise time Electrodes in the basal turn in all cases. In Guinea pig 1117 with venous obstruction the input-output relations were substantially normal

structed at least 15 days previously, and in general their electrical responses were all within normal limits except for a reduced CM maximum voltage in one case The histological findings were also normal

In one of the depressed ears (1120) the electrical responses show that the DC potential may be practically normal with no hair cells present but good stria vascularis, and that even with normal hair cells it may be very low if the stria vascularis is severely injured *All of our experiments are consistent with the interpretation that the endocochlear DC potential is generated by the stria vascularis and not by the hair cells*

The Cochlear Microphonic

The form of the input-output function is very stable The output is linearly proportional to the instantaneous acoustic pressure at low and moderate levels, but goes through a maximum at a high level (Fig 7 illustrates a normal CM response curve) The sound pressure levels at which the first deviation from linearity appears and at which the maximum is reached depend on the acoustic frequency of the stimulus and on the position of the recording electrodes For our control series the median values were 76 and 103 db respectively These levels are so stable, even when the output voltage is greatly depreseed by streptomycin or by venous obstruction, that we were able to infer from elevated values in three cases (1099, 1104 and 1118) that there were conductive losses of 7, 15 and 15 db respectively Otitis media with adhesions had been noted at operation and/or was demonstrated by microscopic examination in each case (In Table I it is the corrected values that are entered)

From the stability of the shape of the CM response curve and of the sound pressure level that elicits maximal response, even when the hair cells are injured and the CM output voltage is reduced, we infer that the shape of the upper part of the CM response curve is mechanically determined by structures and forces outside the hair cells [4]

A third convenient index of CM response is the threshold of visibility of the CM on the oscilloscope This value agrees very well with the sound pressure level that yields a 3 μv peak-to-peak response as determined by extrapolation from measurements at higher level

The final index of CM response is the maximum peak-to-peak output voltage Our median control value is 800 μv

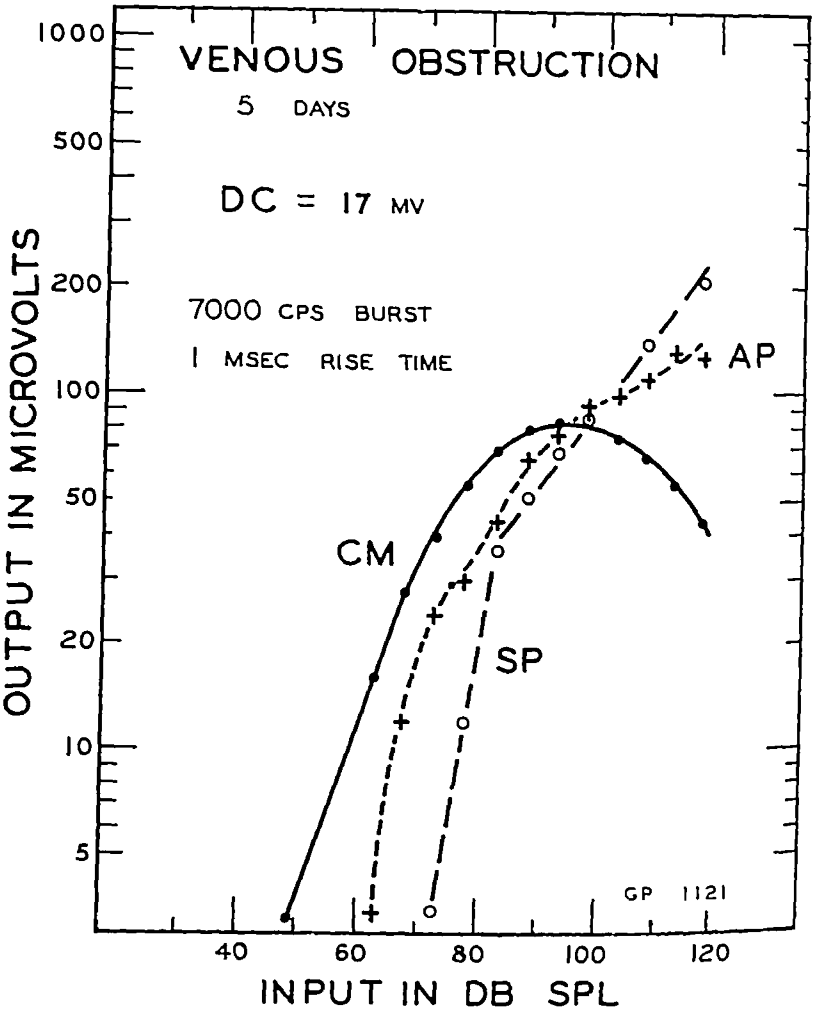

Fig 9 Moderately depressed input-output curves with very low DC endolymphatic potential in an ear with venous obstruction The degenerated stria vascularis and intact hair cells are shown in Fig 4

round window to within 1 mm of the electrodes (see Fig 4) The latter were located in a transition zone between severely and mildly degenerated stria The electrical responses (see Fig 9) were definitely but only moderately depressed The DC potential, however, was only +17 mv

Ear 1121 with venous obstruction, and ear 1096 in the streptomycin series, form a perfect contrasting pair They

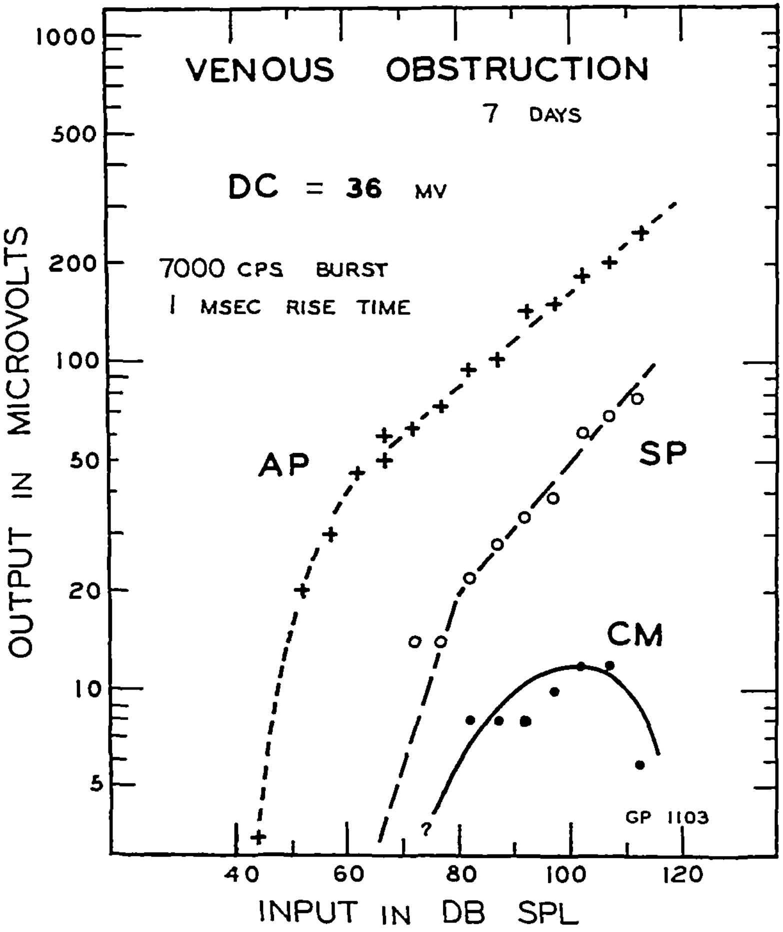

Fig 11 Input-output curves from an ear with venous obstruction This ear showed the strongest AP response relative to CM in the entire series. DC potential is depressed

series offers many examples of this correlation, and the venous obstruction series adds three more

In every case in which no external hair cells remained (within three millimeters of the electrodes) the maximum CM was not more than 3 μv In these cases when a trace of CM remained the threshold was elevated by at least 75 db In other ears, which yielded depressed CM responses five or ten per cent of the normal maximum, and with thresholds

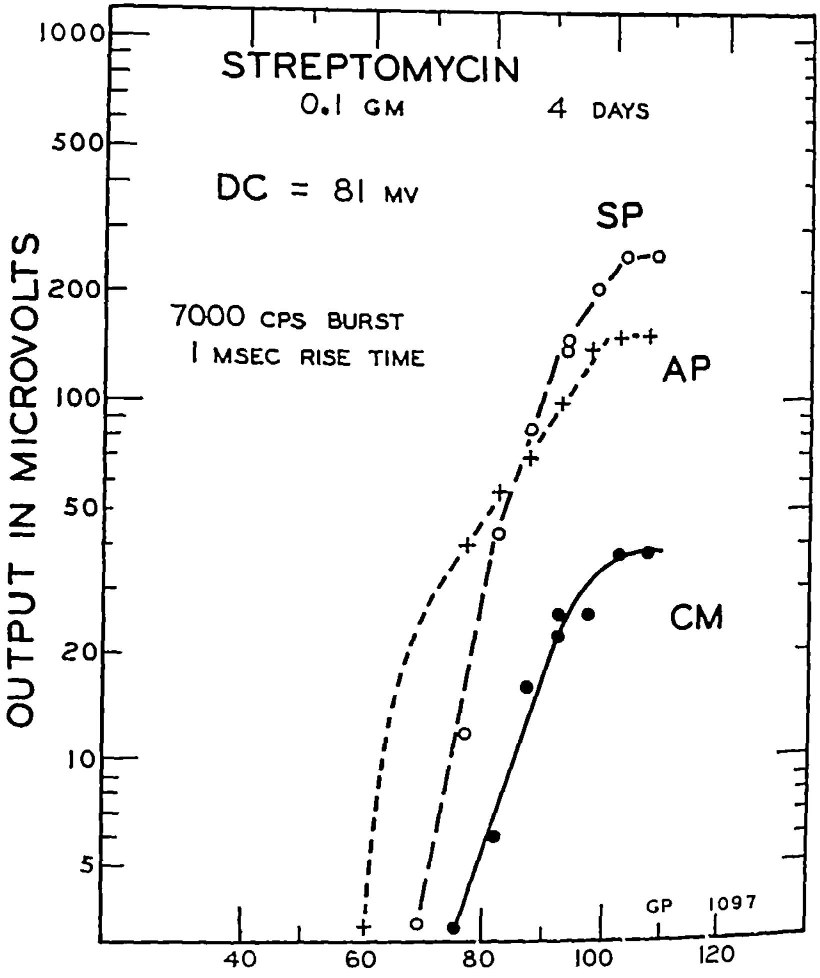

Fig 10 Depressed responses particularly CM in the presence of normal DC endolymphatic potential following treatment with streptomycin The degenerated external hair cells of this ear are shown in Fig 1

The values for all four indices for the individual ears and for the medians of the control series are given in Table I, and full curves are presented in Figs 7 to 12 for six ears that represent various degrees of depression of cochlear microphonic, summating potential and action potential

The cochlear microphonic has for many years been attributed to the hair cells[1] This interpretation is confirmed without exception in the present experiments if we confine the statement to the *external hair cells* The streptomycin en hair cell with a pyknotic nucleus may generate a significant, though perhaps subnormal, cochlear microphonic

The internal hair cells, however, were normal or very nearly normal in appearance in all cases of venous obstruction In six cases of streptomycin poisoning they were at least in fair condition, perhaps a little pyknotic or shrunken We can say with confidence that the contribution of the internal hair cells to the CM response is at most quite small compared to that of the external hair cells In several cases we cannot tell whether the small residue of CM (five to ten per cent of normal maximum) came from good internal hair cells that were present near the electrode, or from scattered or shrunken external hair cells that were found a millimeter or so away Number 1120 shows that internal hair cells can at least appear normal under the microscope without yielding a CM response, but this case is complicated by abnormal stria and low DC potential

In summary *Our evidence strongly supports the hypothesis that the external hair cells are the anatomical locus of the generation of the cochlear microphonic, and that the internal hair cells contribute little or nothing to this response*

The Summating Potential

SP is a DC response to acoustic stimulation The input-output curve of the summating potential is much more variable from animal to animal, and under different conditions in the same animal, than is the response curve of the cochlear microphonic SP is observed as a displacement of the base-line of the CM in the direction indicating that scala vestibuli has become more negative relative to scala tympani (cf 9) A full description of the summating potential is in preparation for publication elsewhere In general, however, *1* the threshold of detection of SP is 20 to 30 db above that of CM, *2* the first segment of the response curve is linear, like CM, *3* the upper segment at sound pressure levels above 100 db SPL is relatively stable and continues to rise up to destructive sound pressure levels (see Figs 7 and 8) The SP response is likely to be larger and more stable in the presence

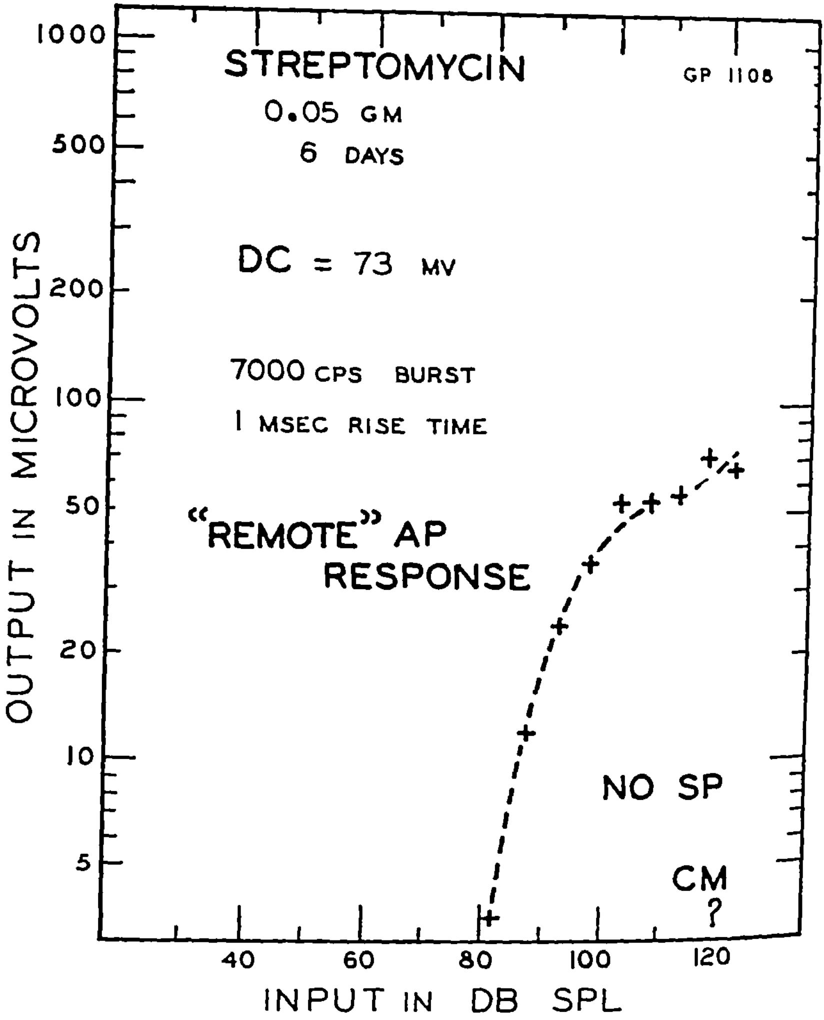

Fig 12 Following treatment with streptomycin the first turn of this ear showed no local responses A typical input-output curve was obtained for the remote component alone of the AP response The degenerated hair cells in the basal turn are shown in Fig 2 Hair cells were still present in the apical turns. The DC potential was normal

elevated 30 db or more, either the external hair cells were badly shrunken and pyknotic in the first turn or, more usually, the electrodes had been placed squarely in the transition zone between absent external hair cells toward the round window and some external hair cells, perhaps with pyknotic nuclei, present within one millimeter apically Apparently a shrunk-spite of the rather small number of cases, the anatomical source of the negative summating potential is the internal hair cells A small contribution from some external hair cells is also possible.

Action Potentials

The normal form and the expected variations in the input-output curve for the N_1 action potential spike in response to a 7000 c p s tone burst will be given more fully elsewhere Fig 7 (1117) shows a fair sample of such a curve, however It rises abruptly from a true threshold response, and it continues to rise, but with varying slope, up to injurious sound pressure levels Two "humps" in the curve are quite typical, one with its maximum near 60 db SPL, the other about 100 to 110 db SPL Convenient arbitrary indices of the AP curve are *1* the SPL at threshold, *2* the microvolt response at 57 db SPL and the microvolt response at 110 db SPL

The selection of these two arbitrary levels is dictated in large part by our impression that the AP response curve is made up of three components, each generated by a separate "population" of neurons and stimulated by a different group of sensory cells (cf 11) The low-intensity population, centering at 57 db SPL, seems to depend quite closely on the presence of a good CM response On the other hand, expt 1097 (see Fig 10) is an excellent example of absence of the low-intensity (CM) population but a nearly normal high-intensity population The CM response in this case is very small (Note that the scale is logarithmic) On the other hand the SP response, which is a less sensitive mechanism, is nearly normal

We believe that the neurons of the low-level population are those activated by the external hair cells and that the CM is part of the mechanism that activates them We further believe that the high-level population centering at 100 to 110 db SPL is the group of neurons activated by the internal hair cells and that SP is part of the mechanism that activates them This hypothesis is specifically formulated for the response of the basal turn of the cochlea to a 7000 c p s tone burst with a 1 msec rise time, but we believe that in general of slight injury, such as mild anoxia, holes in the cochlea, etc, than in fully normal ears

For the present analysis only two indices proved simple and stable enough to be useful the first is the "8 μv threshold," i e the sound pressure level that just elicits an 8 μv SP response, and the SP voltage at the arbitrary level of 110 db SPL The values are given in Table I

Under an injury by either streptomycin or venous obstruction that reduces CM voltage or raises its threshold the SP remains at or near normal values, and sometimes (e g 1103, 1097) it may remain fairly prominent when the CM is greatly reduced or almost abolished The SP follows CM in general, however, in its relation to injury to the organ of Corti and does not, in the crucial experiments (1096 and 1121), follow the resting endocochlear DC potential in its relation to the stria vascularis It appears clearly to be a response of the organ of Corti to acoustic stimulation

The class of cell in which pathological changes correlate most closely with depression of SP is the internal hair cell This cell is rather more resistant to injury by any agent we have used than the external hair cell SP is absent in all eight cases in which the internal hair cells are absent in Turn I It is present in all cases but one in which they are present, even when they are described as "fair", "shrunk" or "pyknotic nuclei" The quantitative correlation is good in all but three cases, all of which are in the venous obstruction series One of these (1104) was complicated by a conductive hearing loss so that SP voltage at 110 db could not be determined, 1103 (see Fig 11) showed a small SP, and 1120 showed no SP both in the presence of "normal" internal hair cells In 1103 we must postulate either partial anoxia of the animal during the test or covert injury to the internal hair cells In 1120 (see Fig 5) there is indirect evidence of poor circulation in the distended capillaries found in stria vascularis and in unusually extensive "hemorrhage and precipitate" in the perilymphatic spaces

We believe that in spite of these two partial exceptions that require additional, although plausible assumptions, and in ound window, causes degeneration first of external, then of nternal hair cells, and then of supporting cells of the organ f Corti The stria vascularis is very little affected

2 The persistence of a normal positive DC endocochlear potential after streptomycin has destroyed the hair cells eliminates the hair cells as possible generators of the DC potential (It is not reasonable to attribute a DC potential of *+70 mv or more in* scala media in the first turn to generators located in higher turns The "space constant" established by Misrahy[3] for the scala media is too small in other words, the basilar membrane and organ of Corti are too leaky electrically to distribute the DC potential very far along the cochlea away from the region of its generation)

3 Extensive venous congestion, both acute and chronic, affects stria vascularis more quickly and profoundly than the hair cells

4 The systematic depression of the positive DC endocochlear potential by venous congestion supports the theory that the stria vascularis is the generator of this potential

5 The effect of venous congestion on the cochlear microphonic, on the summating potential and on the action potentials is variable, depending on the exact degree of injury to various tissues in the neighborhood of the electrodes, particularly the hair cells

6 The DC endocochlear potential is not necessary for the generation of CM (It may, however, serve to make the CM response larger or more sensitive)

7 CM is probably the immediate stimulus to nerve fibers near threshold, but a fairly good AP response is still possible with a very small CM

8 SP is always present when the AP response is greater than that which can be attributed to the "remote response" of the apical region SP, as well as CM, is probably an effective stimulus to nerve fibers

9 Internal hair cells that appear normal under ordinary microscopy may not yield a significant CM response the external hair cell and CM are a sensitive low-level mechanism, and the internal hair cells and SP are a less sensitive and more rugged high-level mechanism This hypothesis incidentally explains how the AP output curve can continue to rise at levels above 105 db SPL, at which the CM output curve is falling

The final rise in the AP curve is assisted by the "remote response" described earlier by some of us[6] A tone burst at levels above about 80 db SPL evokes not only local movements of the cochlear partition and corresponding CM and SP responses, but also a new mechanical wave that in time-course and amplitude corresponds to the envelope of the tone burst This is a mechanical detector (demodulator) action The new mechanical wave activates the apical part of the cochlea that is appropriate to its long wave length, which is determined by the rise-time of the burst The resulting "remote" action potentials from more apical regions add with the action potentials of the neurons that innervate the first turn They constitute a third, very-high-level population

Fig 12 (1108) in which all hair cells, both inner and outer, were absent in Turn I, but in which pyknotic inner and outer hair cells were both present in Turn II, is a beautiful example of a pure "remote" AP response curve Notice that no SP and only a doubtful 3 μv CM could be detected in Turn I

An inference from experiment 1108 is that the detector action that initiates the remote wave does not involve the hair cells It must be a prior mechanical event, like the process that is responsible for the maximum in the CM response curve

CONCLUSIONS

The foregoing observations on cochleas poisoned with streptomycin or depressed by extensive venous congestion, taken in conjunction with our previous knowledge of the electrical potentials of the ear, serve to establish or to support strongly the following conclusions and interpretations

1 Streptomycin, when it has been absorbed by way of the

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ACETYLCHOLINESTERASE AND THE OLIVO-COCHLEAR TRACT OF RASMUSSEN

(Abstract) *

HAROLD F SCHUKNECHT,

Henry Ford Hospital,

Detroit, Mich

A high concentration of acetylcholinesterase is found on the nerve fibers and endings of all four rows of hair cells in the cat cochlea When the olivo-cochlear tract of Rasmussen is cut in the brain stem, the quantity of acetylcholinesterase diminshes greatly, and after several weeks disappears almost entirely

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*The full paper will be published elsewhere

10 The negative summating potential is, in general, more resistant to depression by streptomycin or by venous congestion than either CM or AP

11 Injury by either streptomycin or venous congestion tends to make the SP response function more regular and even to increase the negative SP response above normal (This may be due to elimination of a very vulnerable positive SP response A strong positive SP appeared temporarily during a single experiment on acute venous congestion)

12 The negative SP can still be present in the absence of external hair cells SP has not been seen when internal hair cells are also absent This does not exclude the possibility that external hair cells, when present, may *also* generate SP, but the external hair cells probably produce all or nearly all of CM, and the internal hair cells probably produce all or nearly all of negative SP (The external hair cells are the most probable source of *positive SP,* because both positive SP and the external hair cells are highly vulnerable to injury)

13 The position of the maximum CM response on the intensity axis remains fixed in spite of injury by either streptomycin or by venous congestion This strongly indicates that the maximum in the CM response, and probably also "breaks" in the SP input-output curves, are almost certainly controlled by physical (acoustical or mechanical) factors prior to the bending of hairs of the sensory cells

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SESSION C

May 16, 1957

APPLICATIONS AND LIMITATIONS OF AUDITORY TESTS IN SURGERY OF THE STAPES

(Abstract)

Samuel Rosen,
Mount Sinai Hospital,
New York, N Y,
and
Moe Bergman,
Hunter College,
New York, N Y

The relative sensitivity thresholds of hearing by air conduction and bone conduction, the so-called air-bone gap, seem to be the most meaningful audiologic criterion for the selection of cases for stapes surgery In general, the amount of hearing loss does not enter critically into the decision to operate, if there is a significant air-bone gap Other audiologic measures, such as the discrimination score and tests for recruitment give useful information but, in the presence of a significant air-bone gap do not substantially influence the decision for or against surgery

A technique for determining the degree of fixation of the stapedial footplate, a quantitative Gelle, was described It is the author's experience that such tests are useful only if they can definitely establish whether the footplate is or is not fixed at all While the less rigidly fixed footplate apparently can be more easily *mobilized,* stapes surgery is indicated even in the case of a rigidly fixed stapes, since a fenestra ovalis can be made through the footplate

Questions were raised about the necessity of maintaining an intact ossicular chain for the surgical removal of the air-

NEURALLY ISOLATED COCHLEA
(Abstract) *

KARL LOWY
and
ARNOLD A GERALL,
University of Rochester,
Rochester, New York

Sectioning of the auditory nerve in the anesthetized cat abolishes or greatly reduces the P1-component of the neural click response This observation re-opens the problem of the origin of the several parts of the click response Experiments to determine the nature of these components were undertaken and were reported

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*The full paper will be published elsewhere

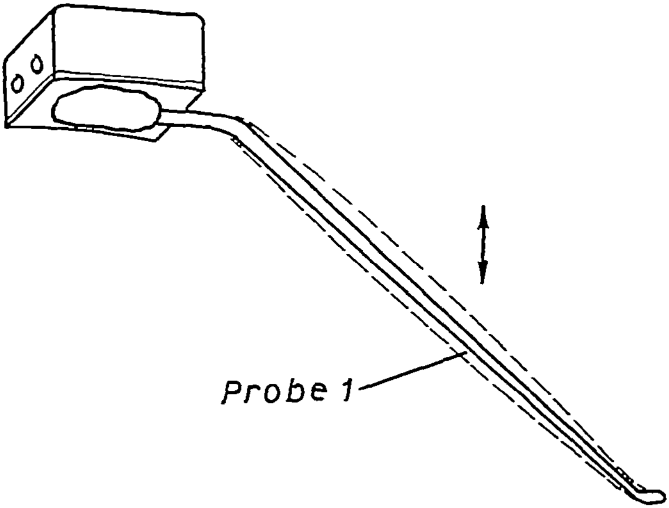
Probe 1

Fig 1.

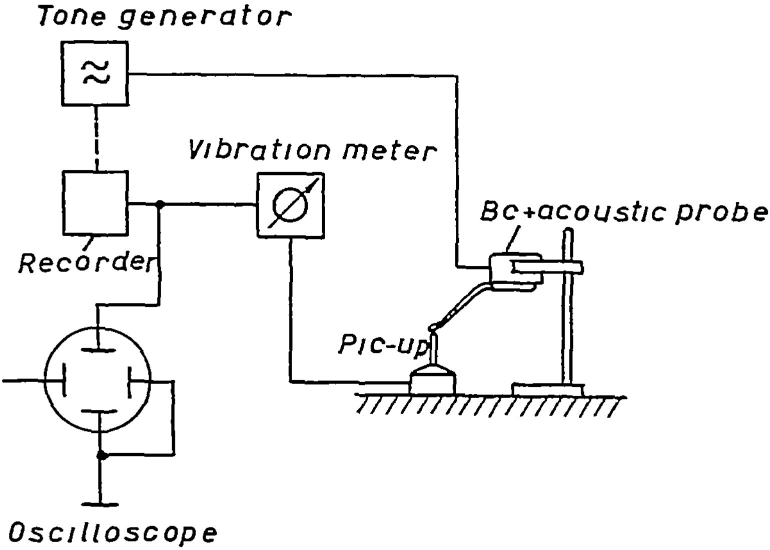
Tone generator
Vibration meter
Bc+acoustic probe
Recorder
Pic-up
Oscilloscope

Fig 2

bone gap, and a case was shown where, despite the fracture and removal of the crura, the post-operative hearing was better than normal It appears that there is not yet a predictable relationship between the pre-operative hearing test findings and the degree of hearing improvement achieved through stapes surgery

THE ACOUSTIC PROBE AND THE DETERMINATION OF STAPEDIAL FIXATION

OTTO H MEURMAN,

University of Helsinki, Finland

In the February issue of *Acta Otolaryngologica,* 1957, I published a report on the use of an acoustic probe for determination of the degree of stapedial fixation The present paper is based, in the main, on the same clinical measurements and some additional technical studies

The work was undertaken to discover the possible value of the acoustic probe in studying the mobility of the ossicular chain prior to mobilization, and in particular to determine whether the stapes is rigidly, or only slightly, fixed to the oval window The pure tone audiogram mostly provides information as to whether the stapes is mobile or immobile Audiometric studies, however, do not reveal the degree of fixation

ACOUSTIC PROPERTIES OF THE PROBE

For the clinical experiments an acoustic probe was used, consisting of an ordinary ear probe attached to the bone conductor of the audiometer, as illustrated in Fig 1 The acoustic properties of this probe were measured at the State Technical Research Institute The purity of tone depends essentially upon the pressure exerted by the probe If the pressure is small, impurity of tone results A thin probe vibrates on its own resonance frequencies, which changes very rapidly by loading the probe The velocity of the probe at various frequencies was tested with the apparatus shown in Fig 2 The curves in Fig 3 indicate that the probe, as well as the bone conductor, is most sensitive at about 500 c p s, where the velocity is greatest The amount of energy loss can also be seen from the curves when comparing the velocity coming through the probe with the velocity of the bone conductor itself Energy transmission is limited to about 0 1 per cent The second probe (see Fig 4), has a different construction the probe itself is thicker than the first and it is attached at right angle to the bone conductor Vibration here occurs along the length of the probe, transverse vibration being largely eliminated Sound transmission is thus entirely altered As shown in Fig 5, there is scarcely any energy loss between the bone conductor and the probe A probe constructed along these lines must be regarded as certainly the most suitable testing device, and it will be used in my further studies

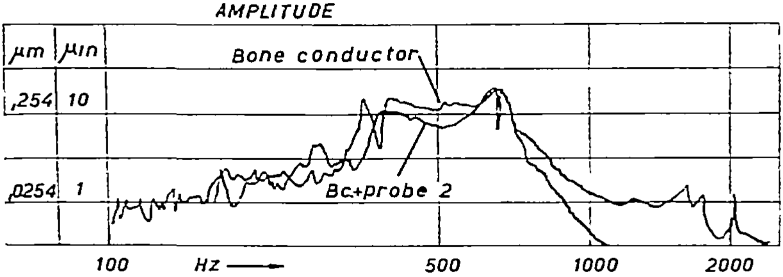

Fig 5

CLINICAL OBSERVATIONS

A threshold curve was determined at 250, 500, 1000 and 2000 c p s, by gently touching the handle of the malleus just below the short process, with the acoustic probe Superficial cocaine anilin anesthesia was used To preclude error, the threshold values for the same frequencies were tested also by keeping the probe in the meatus without touching the meatal walls, malleus or tympanic membrane The values thus ob-

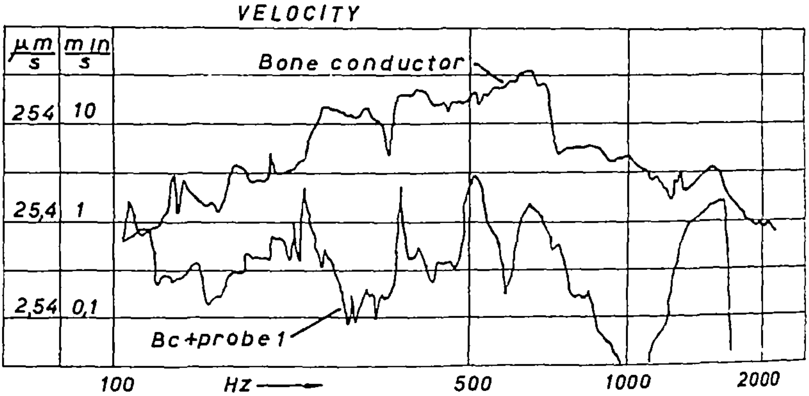
VELOCITY
μm/s
m in/s
254
10
25,4
1
2,54
0,1
Bone conductor
Bc+probe 1
100
Hz
500
1000
2000

Fig 3

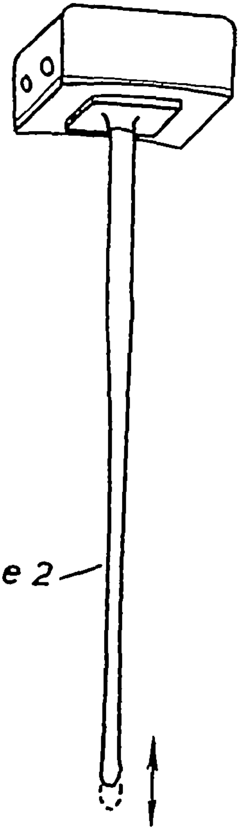
Probe 2

Fig 4

less It is also seen that in Group 1 the ossicle curve shows values considerably smaller than in Group 2 In the former group fixation of the stapes was slight Mostly it was fixed only at the anterior periphery Mobilization in these cases was easy and successful In Group 2, on the other hand, the stapes was extremely firmly fixed In some cases mobilization failed, in some it could be effected only by freeing both the anterior and the posterior periphery

CONCLUSIONS

Clinical studies show that threshold audiograms, recorded by acoustic probe direct from the malleus handle, present values differing according to the degree of fixation If fixation is slight, the ossicle curve gives considerably smaller values than the air conduction audiogram If the stapes is solidly fixed, the ossicle hearing loss at the various frequencies is distinctly greater than in cases with slight fixation In the presence of only slight fixation, the direct contact between the vibrating probe and the ossicular chain causes vibration also in the stapes footplate, or at least in a part of it With an increase in the degree of fixation, the stapes functions more and more as a part of the labyrinthine wall, and its vibration is reduced in accordance From this it follows that, at least in certain cases, it is possible to determine the degree of fixation of the stapes preoperatively by means of an acoustic probe

DIRECT AUDIOMETRY IN AUDIOSURGERY*

(Abstract)

Francisco Antoli-Candela,
Fernando Antioli-Candela,
F Olaizola
and
L Saft,
Madrid, Spain

Modern audiosurgery deals not only with fenestration and tained were always considerably higher than those obtained from the malleus handle

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*This abstract was received and appeared on the official program but the authors were not able to be present to present the full paper

Normally hearing ears served for control purposes The average threshold curve obtained for these ears was taken as the zero curve, by which the hearing loss in the ossicle curves was calculated The series proper is based on 30 otosclerotic ears, 21 of them were operated upon by stapes mobilization after testing with the acoustic probe In these cases the preoperative ossicle curves could be compared with the degree of stapedial fixation noted at operation The following table shows the ordinary air conduction hearing loss and the relative ossicle hearing loss (OC) at 500 and 1000 c p s in two different groups of patients In the first group the stapes was slightly fixed, in the second it was rigidly fixed

TABLE I

Patient No	AC - Loss		OC - Loss	
	500 c.p s	1000 c p s	500 c.p s	1000 c.p s.
GROUP 1				
1	40	35	0	5
5	60	60	25	30
15	50	45	20	20
16	55	55	30	20
18	50	40	10	20
19	60	60	15	5
Mean			16 5	16 5
GROUP 2				
2	54	60	35	60
3	50	45	40	30
7	60	50	45	55
8	65	65	60	45
9	50	55	30	40
11	60	60	30	35
13	55	55	40	35
Mean			40	42 9

Group 1 Stapes fixation slight
Group 2 Stapes fixation rigid

A study of the table readily shows, for one thing, that in Group 1 the air conduction loss is much greater than the ossicle hearing loss, whereas in Group 2 the difference is far region This is because the visual direction of gaze is oblique relative to the internal surface of the tympanic cavity, due to its characteristic inclination This tangential visualization also encounters the obstacles of the short process of the incus and both processes of the stapes

We have attempted to achieve a better visualization of the footplate by means of a lengthened, preaural incision in the anterior wall of the auditory canal just at the edge of the tympanic bone, which at this place forms the bony portion of the canal This permits the uncovering of the edge of the tympanic bone The lifting of the skin that covers both it and the capsure of the temporo-maxillary articulation further permits us to extirpate small or large portions of the bone with the drill Now we can adjust the visual angle so that it may be perpendicular to the footplate of the stapes

Further extirpation and laying back of skin permits enlargement of the visualized space so that the footplate may be projected frontally in the center of the visual field and may thus be manipulated more safely and under better control

THE CARHART-SHAMBAUGH FORMULA USED FOR STAPES MOBILIZATION PREDICTION

FREDERICK R GUILFORD
and
C OLAF HAUG,
Houston, Texas

It has been generally believed and emphasized by Rosen,[1] Kos,[2] Sheer,[3] and others, that it appears impossible at this time to establish audiometrically a workable prediction of the result to be expected from the stapes mobilization operation It is pointed out that variations in oval window pathology resulting in stapes fixation in large part determine the feasibility of mobilization, and that the nature and extent of this fixation cannot be ascertained short of exploratory surgery stapedioclasia for otosclerosis, but also with every technique for the recuperation of any deafness caused by congenital defects in the sound transmission, traumatic lesions and suppurated chronic processes of same, and its healing sequels

With a view to reaching a more exact preoperative diagnosis, and providing beforehand the most adequate surgical technique, we usually carry out a direct audiometry by means of a plastic acoustic conductor connected to a micro-audiometer and placed either on the pathologic formations of the tympanic cavity or on the basic points of the sound conduction, thus enabling us to find out the highest or lowest integrity of the tympano-ossicular apparatus and the permeability of the windows

It also allows us, when performing a mobilization operation, to know more definitely when we obtain a total or partial mobilization of the stapes and the function of the round window

Similar findings can be achieved if we encounter remains of ossicles in the audiosurgery of atresias

NEW APPROACH TO THE INCUDO-STAPEDIAL REGION FOR MOBILIZATION OF THE STAPES *

(Abstract)

LUIS GARCIA-IBANEZ,

Valencia, Spain

Our experience in mobilizing the stapes according to the approach of Rosen has not been good With that approach and working on the neck of the stapes, only one out of three patients who were operated upon achieved a result that was lasting and socially useful

Our attempts to work directly on the footplate of the stapes showed that it is difficult, with Rosen's approach, to achieve good exposure and visualization of the incudo-stapedial

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*This abstract was received and appeared on the official program but the author was not able to be present to present the full paper of the bone-air gap As shown by the results in Tables I and II, the average amount by which this closure fails in our series is 14 6 db

This figure compares very favorably with the differential of 15 db between the post-operative air average and the pre-operative bone average (or 25 db from the corrected bone average), which serves as a basis for the C-S formula In the fenestration prediction it represents the irreversible residual of hearing deficit resulting from surgical disruption of the impedence matching ossicular chain mechanism

TABLE III

Stapes Mobilization—Chances for Closing Air Bone Gap
Based on Series of 100 Cases

% Closed Air Bone Gap	12 9
% Closed Air Bone Gap within 5 db	18

Table III further illustrates the small percentage of possibility of closing the bone-air gap completely or within 5 db This differential between the post-operative air result and the pre-operative bone, which in our series has been so much like that found in the fenestration situation, requires further study to establish an explanation After stapes mobilization, of course, the ossicular mechanism has not been sacrificed and, theoretically, if complete mobilization is successful, hearing should be restored to the level of the pre-operative bone conduction threshold

Middle ear pathological changes present at the time of operation, or following mobilization attempts, probably prevent this theoretical bone-air closure These changes might include friction in movements of the stapedial foot plate, caused by bony spicules and other irregularities of outline following lysis of the stapes, stretching of the incudo-stapedial or incudo-malleolar joint, fibrosis of the annular ligament, tension changes in tympanic membrane and incomplete mobilization of the stapes footplate We must bear in mind that mechanical mobility of the stapes does not necessarily insure adequate physiological mobility of the inner ear fluids

We realize that the otosclerotic focus may result in varying degrees of stapes ankylosis, sometimes preventing successful mobilization, and the difficulties involved in establishing an accurate formula comparable to the fenestration prediction, however, we felt that a study of one of the fenestration prediction formulas on a series of stapes mobilization cases employing the same selection technique by the same audiologist-otologist team, might provide a guide as to what could be expected from the procedure.

TABLE I

Stapes Mobilization—Closing the Air Bone Gap

	Actual Result	CS Prediction
Average Post Op Level	27.9 db	28.3 db
Average Pre-Op Bone Cond	13.3 db	13.3 db
	14.6 db	15.0 db

TABLE II

Stapes Mobilization—Closing the Air Bone Gap
Based on Series of 100 Cases

10 Cases—Better than bone conduction avg by	+4.5 db
2 Cases—Same as bone conduction	- 0 db
81 Cases—Poorer than bone conduction by	-14.66 db
7 Cases—Failures	
100	
Total Difference 100 Cases	-14.6 db

From a study of 100 consecutive fenestrations in a series of 500 cases, the Carhart-Shambaugh[4] formula was found to predict the post-operative result with a high degree of accuracy. We have continued to use this formula in all preoperative audiological evaluations, even though the stapes mobilization was to be the elected procedure. A previous evaluation of an earlier series of the first 100 stapes operations suggested the possibility of the C-S formula for predictive purposes.

It has been our experience that stapes mobilization attempts do not usually restore complete efficiency of the conductive mechanism, as would be demonstrated by closure have the fenestration before the four months' post-operative test was done

While we are aware that our selection has eliminated some unfavorable results, it has also eliminated an equal number of favorable results, as illustrated in Table V

Table VI shows that the sample used was typical of the range of pre-operative levels ordinarily encountered in otosclerotic patients

TABLE IV

Stapes Mobilization—Comparison 1st Post Operative Test 1 to 2 Months Following Mobilization with 2nd Post Operative Test 3 to 4 Months Following Mobilization
Based on Series of 100 Cases

1st Post Operative Average Level	27 94 db
2nd Post Operative Average Level	29 28 db
Total Average Difference	1 34 db
1st Post Operative Average Gain	20 56 db
2nd Post Operative Average Gain	19 22 db
Total Average Difference	1 34 db

TABLE V

Stapes Mobilization—Post Operative Results—96 Eliminated Cases

More than 10 db gain and better than 35 db level Good	35-40 db level and more than 10 db gain or 25 35 db level and 6 10 db gain Partial	Less than 11 db gain and poorer than 35 db level or less than 6 db gain any level Bad
31 Cases	14 Cases	33 Cases
23 69 db level 22 7 db gain	35 5 db level 12 21 db gain	51 db level 1 97 db gain

Our average post-operative stapes level, as compared to the average Carhart-Shambaugh fenestration predicted level, is shown in Table VII The levels of 27 94 db and 28 39 db represent an average difference of only 39 db In Table VIII the range of variance from perfect prediction is plotted It reveals that 48 per cent of the cases were either exactly predicted or were within 5 db of perfection, 76 per cent of

It is our feeling, that given a standardization of pre-operative evaluation involving the same audiologist, and of surgical procedure by the same operator, the main remaining variable in the application of C-S formula is the nature and extent of the otosclerotic pathology which would permit or prevent mobilization of the stapes

From an evaluation of the distribution of mobilization failures in an adequate series, one may be able to predict the percentage of cases which will defy successful mobilization, because of the anatomy and extent of otosclerotic pathology Then, eliminating this group and leaving those who can be mobilized, one may predict, using an audiometric formula such as the C-S, what the expected level will be

In order to investigate this possibility the most recent 100 cases of stapes mobilization, in which one month and four months' post-operative results were available, were studied as to the correlation of post-operative result and C-S prediction The most recent 100 were chosen in order to eliminate the variable of changing surgical technique, and to take advantage of the factor of surgical experience

The surgical technique for stapes mobilization used in this series of cases was a variation of the original Rosen[5] technique, as modified by House[6] Mobilization maneuvers are made through the capitulum of the stapes with curved Rosen explorers If this maneuver does not result in mobilization, attempts are made to mobilize the stapes via the footplate, as described by Rosen Fenestration of the footplate was not attempted in this series Surgical audiometry, adapted from the Goodhill[7] technique, was used in all cases

We chose these cases with both one month and four-month post-operative results because we felt that it was important to establish the degree of stability of the results used in this study Table IV shows that the average change from first post-operative test to second was only 1 34 db

This selection of necessity covered a large group of cases, because, although every patient was contacted for retesting, many failed to return for one of these tests, or went on to our cases were within 10 db of the Carhart-Shambaugh predicted level. Range of variance is further depicted in Table IX, 53 results were better than the C-S predicted level by 9.3 db, and 29 were poorer than the C-S level by 7.7 db, making a total of 82 cases that differed from the exact fulfillment of the prediction by an average of 8.3 db. There

TABLE IX.

Stapes Mobilization—Post Operative Levels Compared to Carhart Shambaugh Predicted Levels
Based on Results of 100 Cases

No Cases		
53	Better Than CS Predicted Level by	9.3 db
29	Poorer Than CS Predicted Level by	7.72 db
82	Differ from CS Predicted Level by	8.3 db
11	Same Level as CS Predicted Level	0 db
7	Failures	
100	Total Cases	

TABLE X.

Stapes Mobilization

Predicted Poor Result Less 11 db gain and Poorer 35 db level any level		Good Prediction More 10 db gain and Better 35 db Level or More 30 db gain any level	
Fulfilled	Not Fulfilled	Fulfilled	Not Fulfilled
5 Cases	6 Cases	60 Cases	10 Cases
11 Cases		70 Cases	

were 11 who obtained a level identical to the prediction, and 7 surgical failures. Twelve cases had a failure result by our standard of less than 11 db gain, together with poorer than 35 db level, or less than 6 db gain any level, however, five of these cases were predicted to be failures, and were classified as selection failures and included in the predictive comparison. On the other hand, seven had a good prediction and actually achieved a failure, and these were classified as true surgical failures and eliminated from the comparison.

Table X demonstrates the success of the C-S formula in

TABLE VI

Stapes Mobilization—Range of Pre-Operative Level
Based on Series of 100 Cases

76 80	1	1
71 75	11	2
66-70	11	2
61 65	11111 11	7
56 60	11111 11111 11	12
51 55	11111 11111 11111 11	17
46 50	11111 11111 111	13
41-45	11111 11111 11111 11111	20
36-40	11111 11111 11111 1	16
31 35	11111 111	8
26 30	11	2
		100

TABLE VII

Stapes Mobilization Post Operative Results Compared to
Carhart Shambaugh Predicted Results
100 Case Series
Results based on 1st Post Operative Test, 1 to 2 Months After Mobilization

Average Pre-Operative Level	48 50 db
Our Average Post Operative Level	27 94 db
CS Average Predicted Level	28 33 db
Total Average Difference	39 db
Our Average Post Operative Gain	20 56 db
CS Average Predicted Gain	20 17 db
Total Average Difference	39 db

TABLE VIII

Stapes Mobilization
Based on Series of 100 Cases

Better Than CS Pred Level by—				
21 db	111	3		
11 20 db	11111 11111 1111	14		
6 11 db	11111 11111 111	13		76%
1 5 db	11111 11111 11111 11111 111	23	48%	
Same as CS Pred Level	11111 11111 1	11		
Poorer than CS Pred Level by—				
1 5 db	11111 11111 1	11		
6 10 db	11111 11111 111	13		
11 20 db	111	4		
21 db	1	1		
Surgical Failures	11111 11	7		
		100		

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AUDITORY FATIGUE AND OCCUPATIONAL DEAFNESS *

H A E VAN DISHOECK,
and
A SPOOR,
University of Leyden,
The Netherlands

INTRODUCTION

In the last several years studies dealing with the effect of noise on man were published by the co-workers of the Leyden Otological Clinic J van Gool studied the methods of recording auditory fatigue and the dependence of the pattern of the acoustic dip on frequency, intensity and exposure time of the stimulating tone H A van Leeuwen reported on the occurrence of noise trauma and noise deafness in groups of employees in different kinds of factories C Rol, together with A Spoor, gave the results of laboratory studies on the traumatizing effect of steady and nonsteady sounds A difference between the Leyden investigations, and all previous studies such as the well-known works of Temkin (1933), Borge Larsen (1939), Rosenblith (1942), Kristensen (1946), Kryter (1950), and the report of the American Standards Association Z 24-X-2 is the use of continuous-frequency audiometry instead of octave audiometry predicting the extremes of good and poor results Of the 11 cases predicted for a very poor result, five were fulfilled and six not fulfilled Of the 70 cases predicted for a good result, 60 cases were fulfilled and 10 cases not fulfilled

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*From the Oto-Rhino-Laryngological Department of the University of Leyden Holland (head H A E van Dishoeck)

In summary, it has been shown that the Carhart-Shambaugh formula for predicting fenestration results may, according to this series of cases, have value in predicting the stapes mobilization result It was shown that the average difference in predicted and actual levels was low, and range of variance relatively small It was demonstrated further that the average amount by which our results fail to close the bone-air gap is almost identical to that which is expected in using the Carhart-Shambaugh formula for fenestration prediction The number of cases achieving levels close to the prediction was great, and the formula's ability to predict good results appeared significant

It is emphasized that further study is necessary to explain all the reasons for failure to close the bone-air gap in the majority of cases Limitations in the formula's use have been illustrated by the fact that although the average difference in predicted and actual result was small, since better and poorer prediction results tend to cancel each other, individual cases may be considerably off from the prediction, also, though the formula had considerable success in predicting good results, it was only 45 per cent effective in predicting very poor results (5 out of 11)

Although much more study is necessary before we will achieve a stapes formula with the predictive ability of the fenestration formulas, we feel that the Carhart-Shambaugh formula, if cautiously interpreted, will serve as a better guide to the expected result in the mobilized cases than is otherwise now available

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be detected, and with some additional measurements on higher levels the exact pattern can be established

EXACTNESS OF CONTINUOUS AUDIOMETRY AS COMPARED TO OCTAVE AUDIOMETRY

Apart from the greater information obtained by continuous audiometry, because the exact pattern of a hearing loss is established, the reproduceability also proved to be superior Alternately three continuous and three octave audiograms were made of the same test person by van der Waal A great number of these audiograms were studied statistically The mean average standard deviation in continuous audiometry proved to be 2 41 db, whereas in octave audiometry, 3 68 db

BACKGROUND NOISE

The great practical difficulty in obtaining reliable audiograms in factories is the fact that the quietest room is not comparable to a specially built silent room of an acoustic laboratory, however, bringing the factory workers to the institute is generally not convenient The examiner, working in a relatively noisy surrounding and finding threshold anomalies, must know what part of the measured hearing loss is due to masking by background noise and what part can be attributed to an acoustic trauma

An investigation of this problem was made by Spoor In a sound-treated room, audiograms of persons with normal hearing were taken during exposure to different kinds and levels of noise, *e g* white noise, industrial noise and octave band noise The audiometer was checked by using as a reference value the average continuous audiogram of 20 young persons without evidence or history of hearing damage It appeared from these investigations, in confirmation of earlier publications, that the audiogram of a normal test person is already disturbed by a noise level of 20 db and more Using telephones with rubber cushions, giving 10-20 db isolation *the acceptable noise level* in the room will be 30-40 db In most circumstances this level can be realized for high tones by simple noise isolation measures, but it is often impossible for the low tones, consequently for low tones the unavoidable

CONTINUOUS AUDIOMETRY

In continuous audiometry a sweep tone is presented to the patient at a certain intensity level The patient's hearing threshold is noted by asking him to indicate at which frequency he begins to hear the sweep tone, and at which frequency the hearing ends By doing this at different intensity levels a complete and very accurate audiogram can be made in a short time The procedure is the contrary of octave audiometry, in which the threshold of some selected frequencies is determined by means of a changing intensity Thus greater and more exact information can be obtained

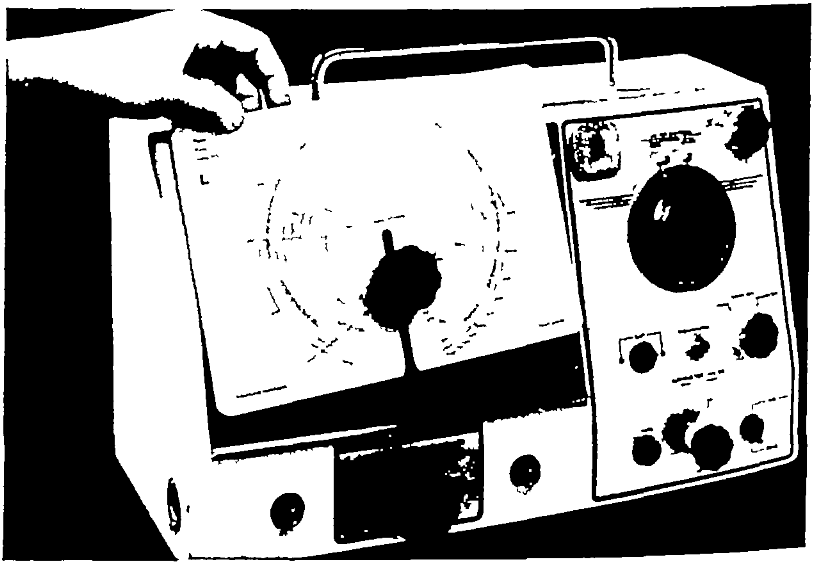

Fig 1 Continuous audiometer with direct recording on the audiocard (Peekel)

The Peekel-audiometer is specially built for continuous audiometry Compensation is made for the low and high frequencies, so that the zero-level of the instrument coincides with the threshold level for normal young persons As from 200-8000 c/s in one sweep any level above thresholds can be tested, this arrangement makes the audiometer ideal for screening If somewhere a hearing loss, such as a beginning acoustic trauma, exists, the localization of this loss will always posure time, however, over 15 minutes does not increase the extent of the dip The conclusion from this fact is that in longer exposure, auditory fatigue depends upon intensity and frequency alone, thus in factory workers the resulting trauma might be limited by the existing noise level, and might not depend on the number of years of exposure Pure tones and noise bands around and above 2000 c/s possess a greater traumatizing effect than lower frequencies of the same intensity above threshold

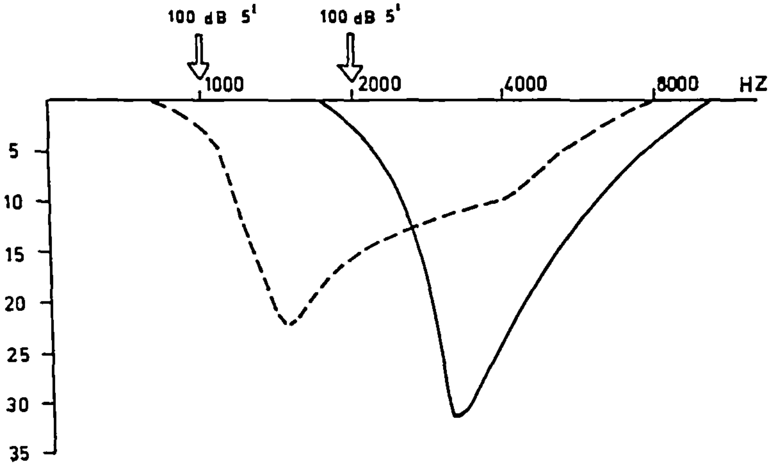

Fig 2 Pure tone dips caused by 1000 c/s and 2000 c/s tones of the same intensity and duration.

From these general properties of the acoustic dip, one may conclude that the notion of a special sensitivity of the C_5 region is erroneous Consequently no theories trying to explain the C_5 dip are needed The origin of the illusion of a preference of the region around 4096 is clearly the result of the measuring at this frequency in octave audiometry Accordingly, the maxima of industrial noise traumata can be located at any frequencies between 2000 and 7000 c/s

A THEORY ON THE ORIGIN OF THE ACOUSTIC FATIGUE AND TRAUMA

Perhaps the tonal dip might be explained by the following noise level is mostly higher than is acceptable, and thus an inaccuracy of the audiogram must be reckoned with By establishing the threshold shift of normal persons under these unfavorable circumstances, a reference value for pathological audiograms, taken under the same circumstances, can be obtained Hearing losses as large as, or smaller than, this threshold shift cannot be measured For instance, when a dip of 10 db is measured, and the threshold shift by background masking in this frequency region is 15 db, then the real dip, when measured in a silent room, would be 25 db The average audiogram of 20 normal young persons, taken in a relatively silent factory room, having a background noise level of less than 40 db in each octave band, proved to be for the higher tones in good accordance with the curves of Dadson and King, and Wheeler and Dickson Under 100 c/s an apparent hearing loss, due to low-pitched background noise was present In experienced listeners the differences between the readings in a silent room and in the presence of a background noise are smaller than in unexperienced listeners

EXPERIMENTS WITH SINGLE PURE TONES

Auditory fatigue is characterized by a temporary threshold rise of a typical pattern—a tonal dip The threshold at the frequency of the stimulating tone itself is not, or only slightly disturbed The maximum of the dip is situated approximately one-half octave above this frequency For dips caused by 1000 c/s and higher tones the slope of the dip on the side of the lower frequencies is steep and on the other side much more gradually, showing some small depressions The steepness, and thus the place of the maximum of the dip in regard to the stimulating frequency, depends on the size of the dip Small dips are bowl-shaped with their maximum on a higher frequency The extent of the dip depends on the sensitivity of the testees and the traumatizing power of the stimulus In steady pure tones this power depends on intensity, frequency and up to a certain limit on the exposure time Thus the same small dip can be obtained when using a certain tone of high intensity during a short time, or of low intensity during a long time Lengthening of the ex-

Ranke and Reboul, the maximum of this distortion is situated about one-half octave above the stimulating frequency, thus on the place of the maximum of the dip We assume that this part is damaged by such an inadequate stimulation The amplitude of the swinging is higher nearer to the stimulating frequency, which fact agrees with the slope of the curve and the place of the maximum of the dip Notwithstanding the relatively large movements, this inadequate form of stimulation causes no hearing sensation Perhaps the fact that in high intensities a pure tone sounds more or less impure, is due to this distortion

Frequent repetition of the reversible auditory fatigue, without sufficiently long period of recuperation, results in an irreversible lesion of the organ of Corti, that is, in an acoustic trauma

FATIGUE CAUSED BY PURE TONES OR BY A WHITE NOISE

The effect of stimulation by two pure tones proved to be the combination of two separate dips Consequently it might be possible that, if an employee is traumatized by a high pitched noise and he is transferred to a department having a low pitched noise, an additional trauma for lower frequencies will result Fatigue caused by one-third octave bands proved to be similar to the effect of pure tones

As a white noise is the combination of a great number of frequencies, the resulting trauma will depend upon the sensitivity of the ear and the traumatizing power of the different frequencies The frequency bands around 2000-3000 c/s are dangerous, because the threshold of the ear is low, and the traumatizing power of these higher tones is great The trauma of a white noise proved to be a broad bowl shaped dip, extending from about 3000-7000 c/s, consequently, in an industrial noise the energy in the 2000-3000 c/s band is of great importance

EXPERIMENTS WITH PULSE TONES AND PULSATING NOISES

Rol and Spoor studied the traumatizing power of non-steady sounds as compared to the better known traumatizing theory The stimulation pattern of the basilar membrane by a pure tone, as established by its masking effect, betrays what happens when acquiring a tonal dip The part around the stimulating frequency is strongly but adequately stimulated Clearly this physiological, adequate stimulation results in the hearing of a pure tone, and none, or only a small

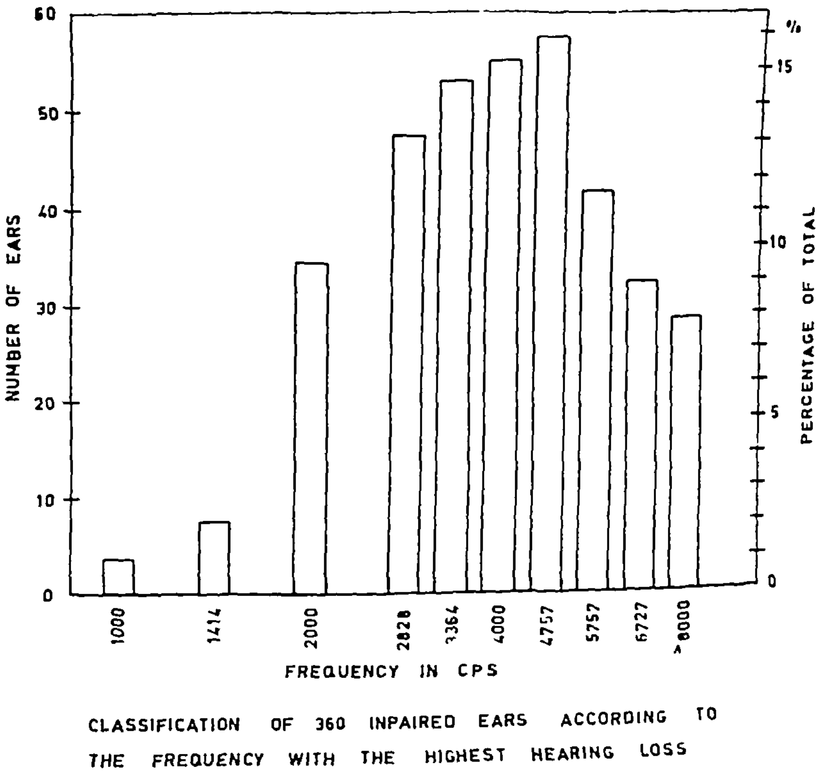

Fig 3 Classification of 360 noise traumata according to the frequency with the highest hearing loss

threshold rising, can be detected afterwards, moreover, the perstimulatory loudness adaptation is present around this stimulating frequency, and not above or below

As is demonstrated by von Bekesy the basilar membrane between the stimulating frequency and the windows suffers distortion due to swinging According to the calculations of

Intermittent stimuli are less traumatizing than continuous stimuli of the same calculated overall intensity

Increase of the pulse duration, the pulse-rate being constant, causes a greater increase of trauma than would be expected from the corresponding increase of the overall-intensity (see Fig 5)

In the same way it was established that increase of the pulse-rate, the pulse-duration being constant, has a greater influence on the traumatizing power than on the calculated overall-intensity of the tone (see Fig 6)

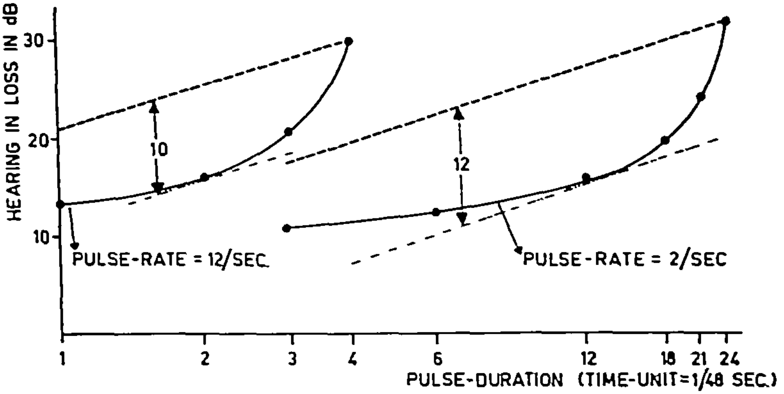

Fig 5 Hearing losses caused by intermittent 2000 c/s stimuli with pulse-rates of 2 and 12 per sec. The upper-dashed lines indicate the hearing losses corresponding to the continuous stimuli of the same overall-intensities

The difference between the trauma caused by an intermittent pure tone and that caused by a continuous one of the same calculated overall intensity was maximal, *viz* 7 to 12 db for a pulse interval ratio of about 1 1 When keeping the pulse interval ratio constant, it appeared that a pulse-rate of 8 per second is more harmful than one of 2 per sec If both noise and superimposed peaks are traumatizing, the effect of the total noise proved to be equal to the sum of the traumatizing powers of the components

The well-known deafness risk criteria are calculated from the threshold curve of the ear and from the greater trauma-

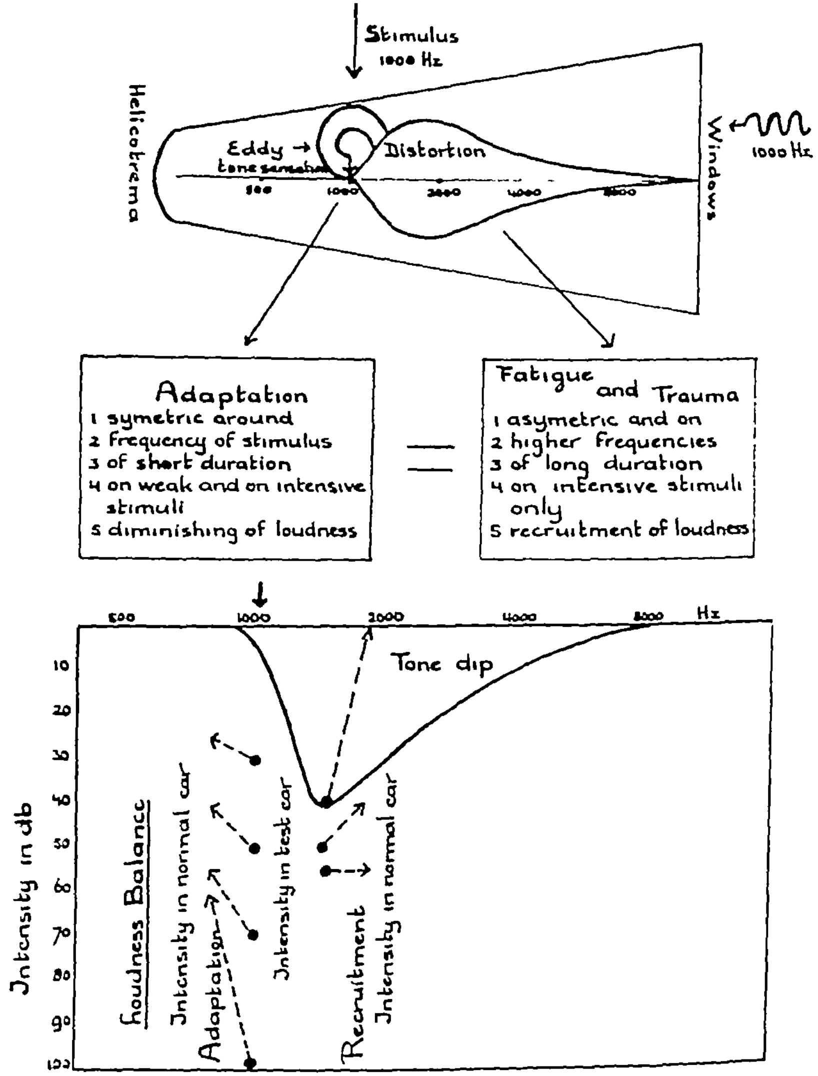

Fig 4 Schematic representation of cochlear mechanisms underlying adaptation and fatigue.

power of steady sounds Intermittent pure tones, an intermittent white noise, synthetically constructed sounds imitating pulsing factory noises, and the recorded noise of a pneumatic drill, were used It appeared that a sound-level meter, whether or not combined with band filters, does not give exact values for the traumatizing power of pulsating sounds

INDIVIDUAL DIFFERENCES IN SENSITIVITY TO NOISE

It is a fact of common experience that among workers who are exposed to the same noise intensities, considerable differences in acoustic trauma exists Even the difference between the left and right ear of an employee can be very great

As we mentioned above, the tolerance curve (see Fig 7) may give us an idea of the traumatizing threshold of different subjects Usually, however, an above threshold method is employed, either by measuring the dip caused by a pure tone or by a noise In order to study this problem, van Leeuwen exposed 108 ears to 2800 c/s tone of 100 db during three minutes As a tonal dip changes very rapidly in size, the resulting dip was measured by means of continuous audiometry in one minute, beginning one-fourth minute after the cessation of the stimulating tone

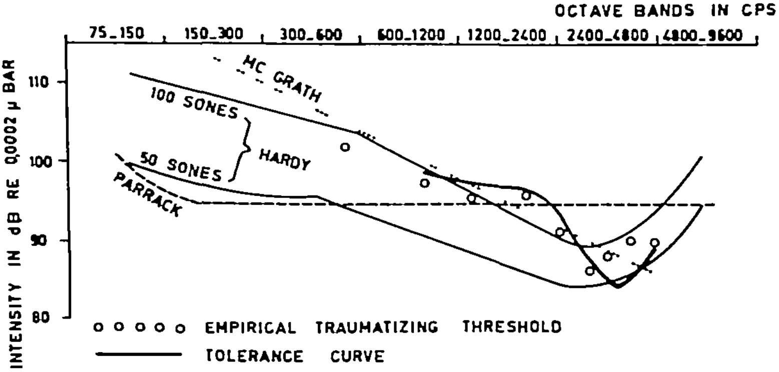

Fig 7 Deafness risk criteria, empirical traumatizing threshold and tolerance curve

Threshold shift in db stimulus 2800 c/s 100 db 3 minutes		No of Ears
0	-2-+2	26—24%
5	3- 7	27—25%
10	8-12	33—31%
15	13-17	8— 7%
20	18-22	7— 6%
25	23-27	4— 4%
30	28-32	3— 3%

tizing of the high tones In order to establish this line experimentally Rol determined, in a number of testees for several tones, the minimum stimulation necessary to cause fatigue This empirically obtained curve differs, especially for the so important 2000-3000 c/s band, from the theoretically calculated curves (see Fig 7) It is known that the social validity for hearing of speech depends for a great deal on the range above 1500 c/s Thus, especially, excess of energy in the 1000-3000 c/s band will endanger the speech intelligibility

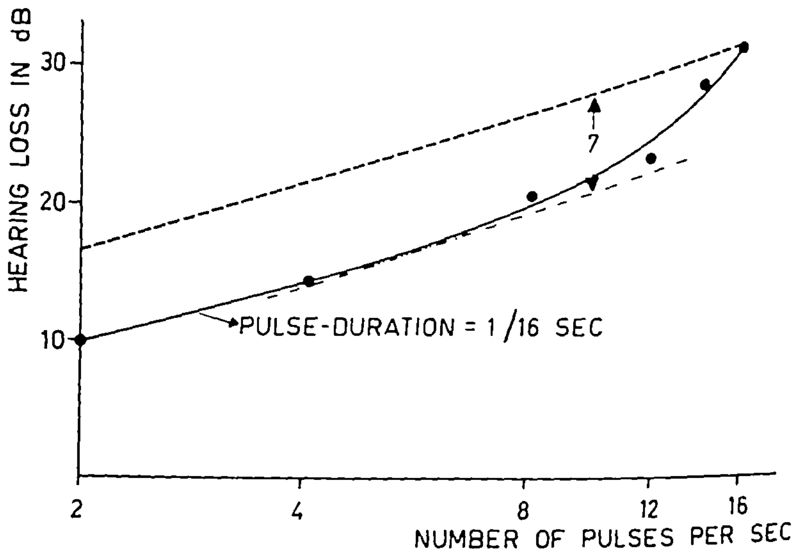

Fig 6 Hearing losses caused by intermittent 2000 c/s stimuli with a pulse-duration of $\frac{1}{16}$-second The upper line indicates the hearing losses corresponding to the continuous stimuli of the same overall-intensities

An attempt was made to establish this tone-sensitivity individually and in a quick and easy way Departing from the supposition that a tone becomes uncomfortable when the traumatizing threshold is reached, we asked our testees to indicate at which intensity a pure tone acquires an impure and sharp character Indeed, the curve in this way obtained, the tolerance curve, proved to be a good criterion for the individual sensitivity of noise (see Fig 7)

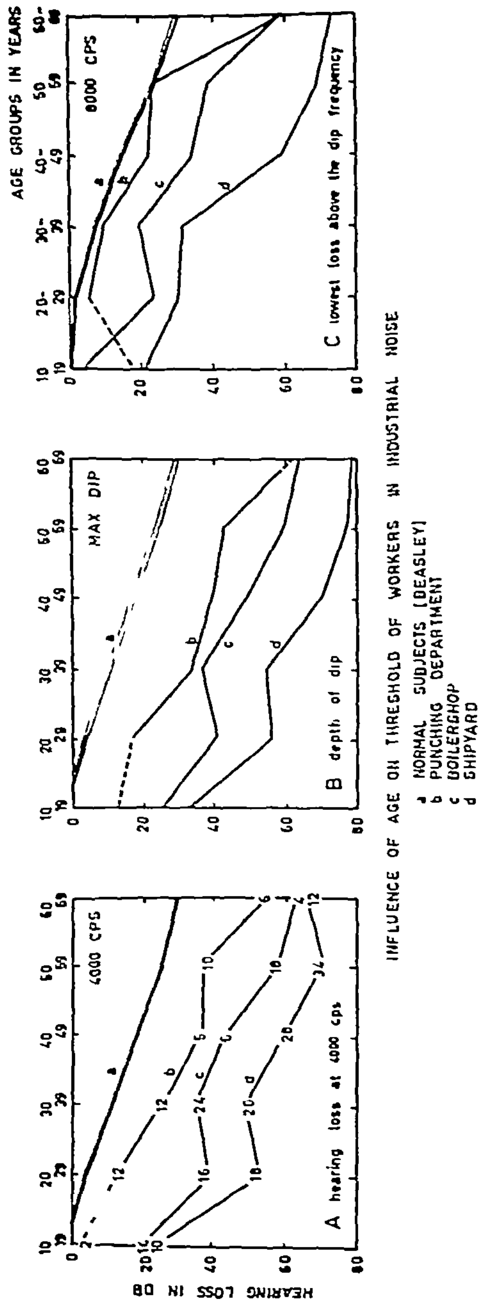

Fig 9 The influence of age on the hearing of employees in different departments.

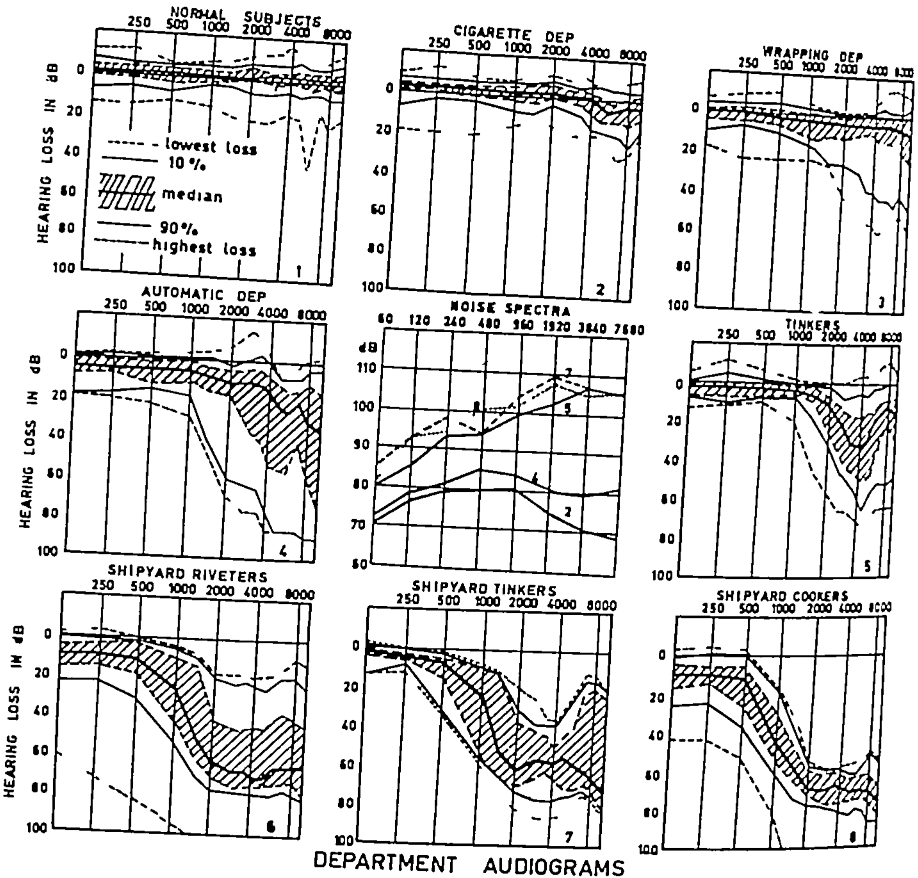

Fig 8 Combined audiograms of employees in departments with different noise levels

From these results we may conclude that considerable individual differences in sensitivity exist Against 24 per cent without threshold shift, 20 per cent proved to have a threshold shift, varying from 15-30 db

NOISE TRAUMA AMONG FACTORY WORKERS IN DORDRECHT

In order to study the correlation between industrial noise level and resulting hearing loss, van Leeuwen classified 279

SUMMARY

From our studies we may conclude that a certain average hearing loss belongs to a certain noise level After some months of exposure the amount of hearing loss hardly depends on the exposure time any more, but mainly on the noise level to which the factory worker is exposed In a relatively short time a trauma is acquired corresponding to the noise level, and thereafter, from this cause the hearing loss does not increase very much. A greater damage may occur when the employee shifts work to a department with a higher noise level or with another pitch. When in course of time presbycusis develops, hearing loss from this cause is added to the existing acoustic trauma Thus, a noise trauma acquired in youth may be unnoticed, but at a higher age this same trauma may be the cause of a hearing impairment for speech This consideration may have important legal consequences

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employees of ten noisy departments of six different factories on the Isle of Dordrecht The audiograms of the employees of each department were combined by considering the median curves and checking them statistically with a group of normal controls

It appeared that these department audiograms could be classified according to the prevailing noise levels This fact agrees with the above mentioned conclusions, that, generally speaking, the size of the trauma depends mainly on the quality and intensity of the stimulus, and not on the time of exposure to noise

In comparing the audiograms of newly appointed employees after a day's work, and the next morning, their capacity for recovery could be established In those who worked some years in a certain department, this recovery was practically absent, moreover, the very important fact was found, that the post-working audiograms of the newly appointed workers resembled closely those of the older employees This observation suggests that repeated acoustic fatigue results in a permanent trauma of the same size From this supposition we may expect that in each department the mean audiograms of different age groups, corrected for presbycusis, should present the same degree of trauma, particular for that department This conception proved, indeed, to be substantially true, only a slight deterioration occurring in the course of the years, which is not accounted for by presbycusis

From these observations, too, the important fact appeared that the permanent trauma is already acquired after a relatively short exposure time

Van Leeuwen calculated the average degree of trauma in groups of workers of about the same exposure time to the same noise level, in order to see whether there was an increase in loss in the groups with longer exposure to noise Since longer exposure and higher age are inevitably linked together the influence of presbycusis was eliminated by correcting the individual audiograms It appeared that most of the damage is done the first year of exposure to noise if the intensity of the exposure stimulus were raised or lowered

METHOD AND PROCEDURE

Six listeners, ranging in age from 23 to 35 years, served in this experiment All had normal hearing and all data were collected monaurally, using the right ear

A PDR-10 earphone, which was encased in a doughnut-type cushion (NAF-48490-1) and mounted on a head band, was used to produce pure tones and noise The apparatus permitted the measurement of quiet absolute thresholds, the measurement of masked thresholds,* and the exposure of the ear to intense noise The test tone was generated by an audio oscillator The output of the oscillator was fed to an electronic switch, two attenuators in tandem, a mixer, a matching transformer, and then it was terminated by the earphone The output of a noise generator was passed through an attenuator to an amplifier For the measurement of masked thresholds, the output of this amplifier was fed through a matching transformer to the mixer in the tone circuit When the noise was to be used as an exposure stimulus, the output of the amplifier was put directly across the earphone Only high fidelity components were used, and switching devices allowed the experimenter to select the appropriate circuit and to keep all terminals properly loaded

Each listener was run individually in eight experimental sessions At each session, the absolute threshold at 4000 c p s was determined, the listener was exposed for three minutes to a noise of uniform spectrum level (60-7000 c p s), and the recovery of the threshold at 4000 c p s was traced for 13¾ minutes The first determination of a post-exposure threshold was completed 15 seconds after the cessation of the noise During the remainder of the session, a threshold measure was completed every 30 seconds

At each session a different level of noise was used There were eight levels, which ranged in overall intensity from 85 db to 120 db (*i e* 0 0002 microbar) in steps of five db These

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*The data for the masked thresholds are not reported

TEMPORARY HEARING LOSS AT 4000 CPS AS A FUNCTION OF A THREE-MINUTE EXPOSURE TO A NOISE OF UNIFORM SPECTRUM LEVEL *

JAMES D MILLER,

Indiana University,

Bloomington, Ind

INTDODUCTION

The results of several experiments indicate[2 3 5 6 7 10] that the form of the function relating temporary hearing loss to the intensity of the exposure stimulus is complex As the intensity of the exposure stimulus is increased from a low value, temporary hearing loss remains at or near zero With further increases in intensity, the amount of loss at first positively accelerates, and then increases linearly up to high intensities At the highest intensities, temporary hearing loss *may show no further increase, or it may,* in fact, decline, with an increase in the intensity of the exposure stimulus This experiment was designed to provide further information on this relationship, as well as to help answer the following questions

1 How does the relationship between temporary hearing loss (THL) and intensity differ from listener to listener?

2 How does this relationship change as the threshold recovers?

It is well-known that wide individual differences in THL are observed when all listeners are exposed to the same stimulus[1 8 9] Answers to the two questions listed above would enable one to predict how the same individuals would differ the noise was defined as the single measurement, which was completed then The next two measurements, which were completed 45 and 75 seconds after exposure, were averaged to define the post-exposure threshold at 1 minute after the cessation of the noise The next four measurements of the threshold were averaged to define the post-exposure thresholds at 2½ minutes after the exposure The post-exposure threshold at 6 minutes after the exposure was defined as the average of the ten measurements of the threshold obtained between 3¾ and 8¼ minutes after the cessation of the noise Likewise, the post–exposure threshold at 11 minutes was defined as the average of the ten measurements of the threshold in the interval 8¾ to 13¾ minutes after the exposure

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*This paper is part of a thesis submitted in partial fulfillment of the requirements for the Doctor of Philosophy degree in the Department of Psychology Indiana University The research was supported in part by the United States Air Force under Contract No AF 18(600)-571 monitored by the Operational Applications Laboratory Air Research and Development Command Bolling Air Force Base, Washington 25 D C This is Report No AFCRC-TN-56-70 ASTIA Document No AD-110052

For each listener, THLs were computed for the different times after exposure by subtracting the pre-exposure threshold from the post-exposure thresholds just defined

In order to detect and to avoid any cumulative auditory effects of this series of exposures, the following precautions were taken For a given listener, successive sessions were separated by at least 48 hours Audiograms (500-8000 c p s) were taken at the beginning of each session If these thresholds were not within six db of their values at the previous session, then the session was terminated, and the exposure was delayed 24 hours

RESULTS

To check on the possibility that there were effects due to either practice or the repeated exposures to noise, the pre-exposure thresholds for the individual listeners were plotted against sessions No consistent trends appeared in these curves Also, the mean THLs for Session II to VII were examined In each of these means, the six listeners and the six intensities (90-115 db) were represented, since over this portion of the experiment noise intensities and sessions were counterbalanced over listeners No trends toward greater or smaller THLs were noted, thus, there was no evidence for changes in THLs due to practice or to the repeated exposures to noise levels are estimates of the SPL under the cushion The level in a 6-cc coupler would be about 8 db greater Each listener was exposed at each of these eight levels The intensity of the noise was 85 db at the first session and 120 db at the last session The intermediate noise levels were assigned to listeners and sessions by means of a 6x6 latin square which was selected randomly, thus, for Session II to VII and for noise intensities 90 to 115 db, the effects of sessions and intensities were counterbalanced

The threshold measurements were obtained by the method of adjustment The listener controlled the intensity of the tone by means of an attenuator which had a range of 60 db with steps of two decibels, he was instructed to bracket his threshold by manual adjustment of the attenuator A test tone was presented for a 15-second period By this method the listener was allowed 15 seconds to adjust the tone to his threshold At the end of the 15-second period, he reported the attenuator reading at which he could just detect the tone When repeated measurements were obtained, there was a 15-second period of silence between the successive measurments

The test tone was interrupted once per second by an electronic switch It was on for 7 seconds and off for 3 seconds The rise-fall time was 50 milliseconds Another attenuator was in tandem with the one that the listener manipulated From trial to trial the experimenter haphazardly varied the amount of attenuation in the second pad This was done so that the listener would not be influenced by his settings on previous trials

Temporary hearing loss (THL) is defined as the difference in decibels between the pre-exposure threshold and the post-exposure threshold The pre-exposure threshold was defined for each listener as the mean of five determinations of the threshold which were obtained immediately before each exposure It was desirable to obtain the most reliable measure of the THL produced by each intensity of the noise after various periods of recovery For this purpose the following variables were defined for each listener at each session The post-exposure threshold at 15-seconds after the cessation of cessation of the noise roughly parallel the THLs 15 seconds after the exposure. Although not shown in Fig. 1, the curves for the THLs 2½ minutes and 11 minutes after the exposure seem to fit into the family of curves. The mean THL for the different times after exposure is given for each intensity of noise in Table I.

Because of individual differences, the basic relationships among THL, time after exposure, and the intensity of the noise may be distorted by averaging all listeners together. It is important to examine the data for the individual listener, and the data are plotted in this way in Fig. 2.

TABLE I

THE MEAN THL AT 4000 C.P.S. FOR DIFFERENT TIMES AFTER THE EXPOSURE AND EACH OVERALL INTENSITY OF THE NOISE

Time After Exposure	INTENSITY OF THE NOISE 85	90	95	100	105	110	115	120
15 seconds	4.0	4.4	9.3	14.5	23.7	28.5	38.3	46.2
1 minute	.6	1.8	3.7	9.8	14.5	17.9	26.0	27.5
2½ minutes	2.2	3.3	5.3	9.0	13.0	15.6	21.0	22.1
6 minutes	1.1	1.6	3.2	6.6	9.8	13.0	17.3	15.2
11 minutes	1.1	1.3	2.6	5.9	8.4	11.9	14.5	12.7

Consider the data for JF shown in panel A. The THLs determined 15 seconds, 1 minute, and 6 minutes after the exposure are shown by the open circles, the filled circles, and the squares respectively. Over their early portions these curves are positively accelerated, and then they become almost linear. That is, once THL has become as large as 15 or 20 db., the remaining portion of the curve can be approximated by a straight line with a slope of about two.

The curves for the other listeners show either an inversion or a leveling off when the highest intensities are reached. This fact will be discussed later. For the present purposes, only the data up to a point of the inversion or leveling off will be considered. This is done by finding for each listener the noise intensity at which the curve in Fig. 2 for THL 6 minutes after the exposure either shows a maximum or levels off. An arrow indicates this intensity for each listener. All THLs for intensities to the right of the arrow are disregarded

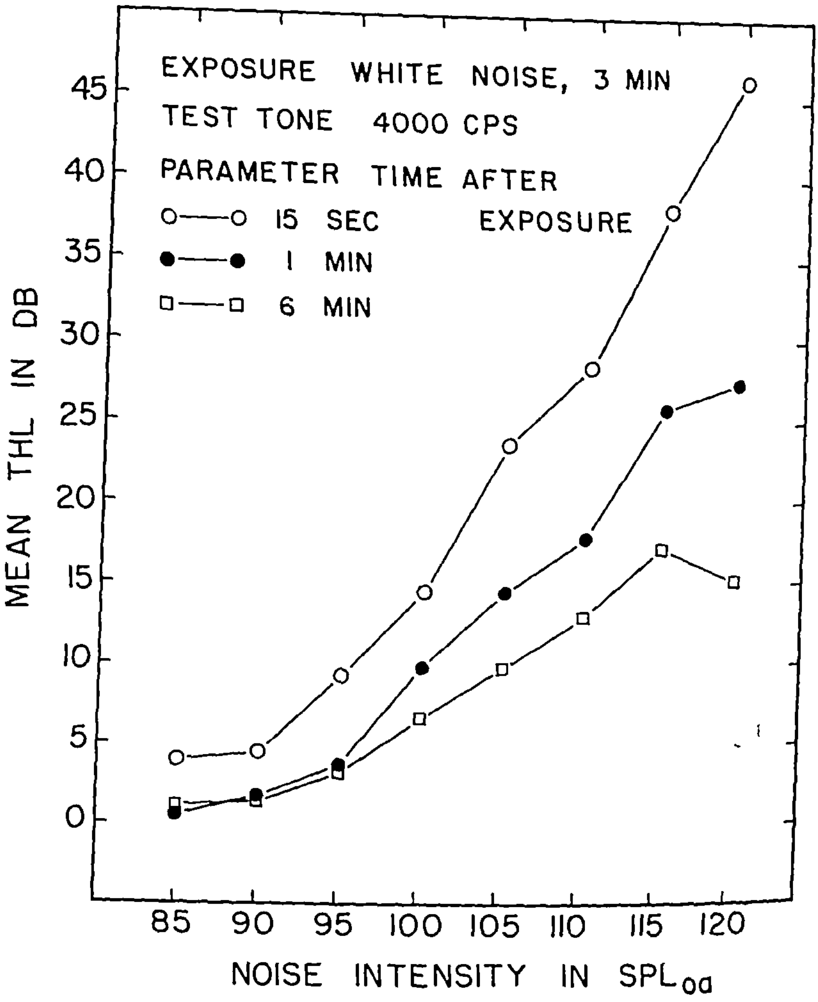

Fig 1 Temporary hearing loss at 4000 c p s as a function of the intensity of a 3-minute exposure to white noise The parameter is the time after the cessation of the noise Each point is the mean of the results for six listeners

A plot of THL against the intensity of the noise is shown in Fig 1 Each point is a mean based upon the results from the six listeners The parameter is time after exposure The curve for the THLs determined 15 seconds after the exposure is positively accelerated over its early portions, and then it becomes approximately linear with a slope of about one and one-half Except for the exposure to 120 *db*, the curves for the THLs one minute and six minutes after the cessation of the noise roughly parallel the THLs 15 seconds after the exposure. Although not shown in Fig. 1, the curves for the THLs 2½ minutes and 11 minutes after the exposure seem to fit into the family of curves. The mean THL for the different times after exposure is given for each intensity of noise in Table I.

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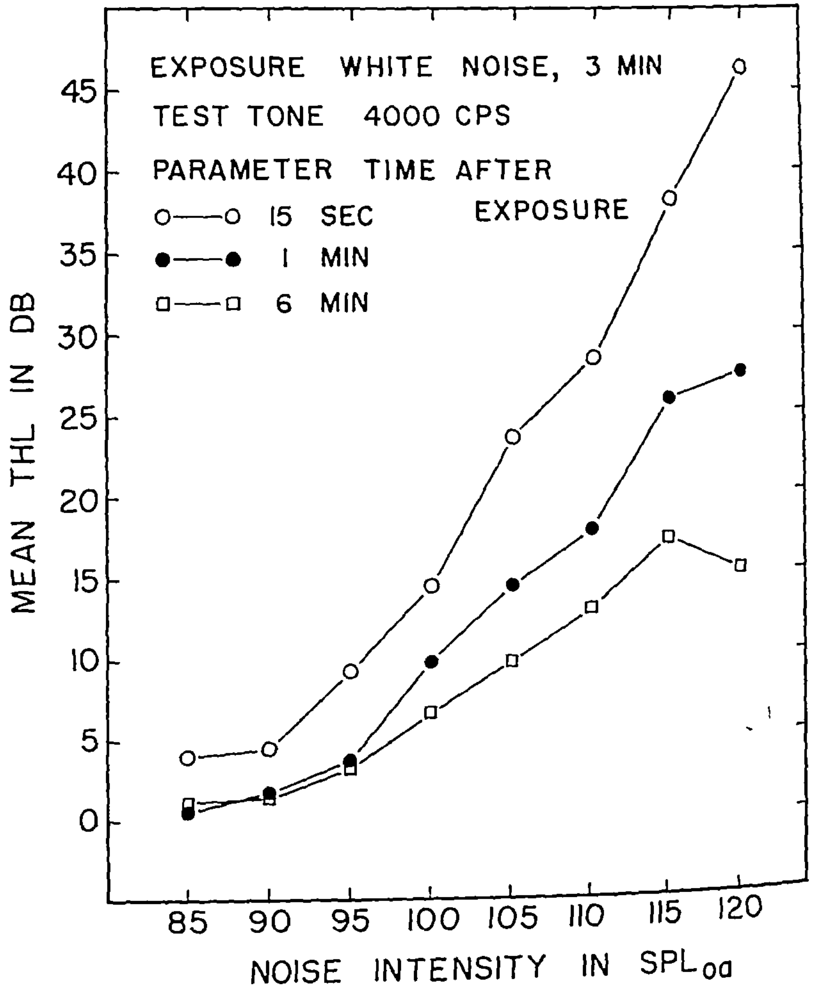

Fig 1 Temporary hearing loss at 4000 c p s as a function of the intensity of a 3-minute exposure to white noise The parameter is the time after the cessation of the noise Each point is the mean of the results for six listeners

A plot of THL against the intensity of the noise is shown in Fig 1 Each point is a mean based upon the results from the six listeners The parameter is time after exposure The curve for the THLs determined 15 seconds after the exposure is positively accelerated over its early portions, and then it becomes approximately linear with a slope of about one and one-half Except for the exposure to 120 db, the curves for the THLs one minute and six minutes after the

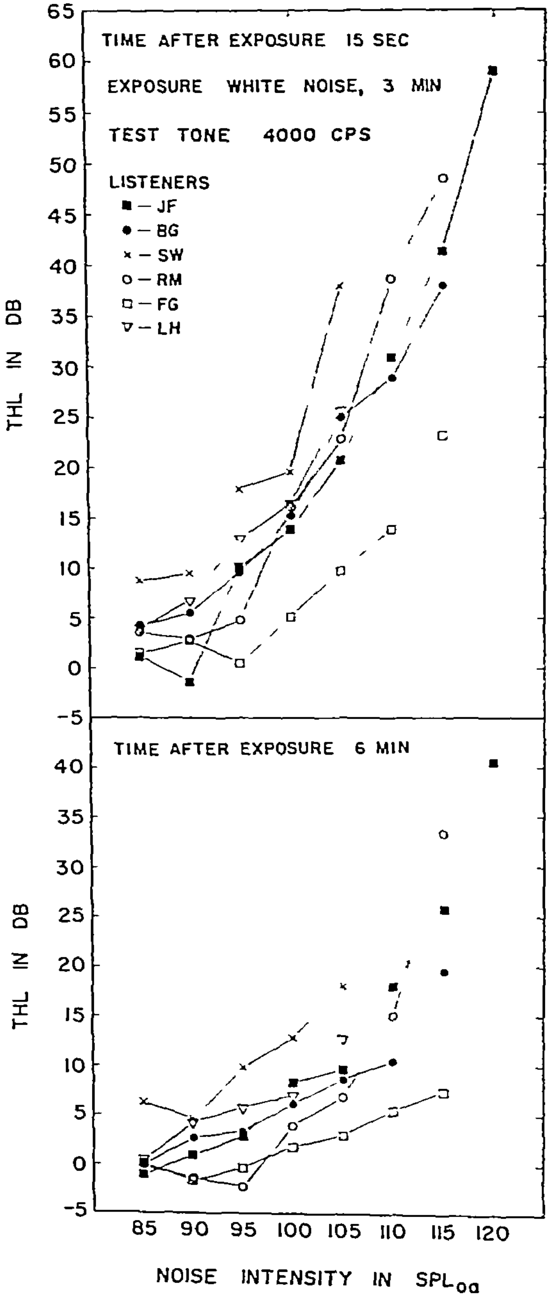

Fig. 1. A comparison of the curves for the individual listeners showing THL at 4000 c.p.s. as a function of the intensity of 3 minute exposure to white noise. The upper panel shows the THLs at 15 seconds after the cessation of the noise. The lower panel shows the THLs at 6 minutes after the cessation of noise. These data were taken from Fig. 2 but only the data up to the point indicated by the arrows are included. See text for explanation.

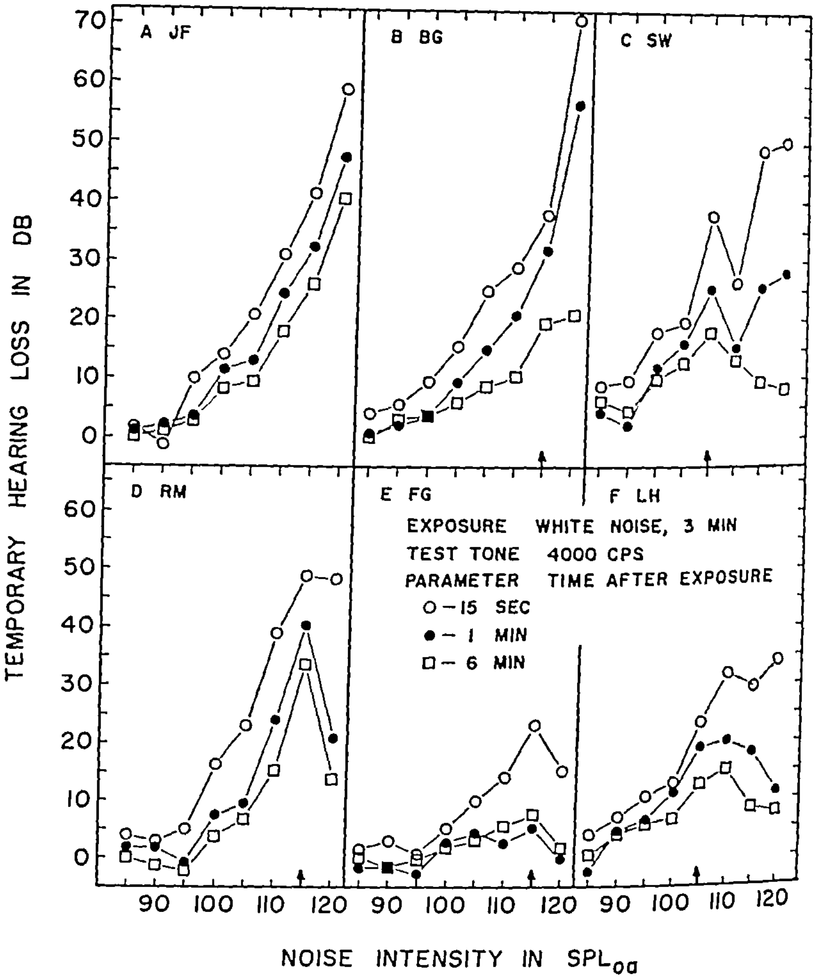

Fig 2 Curves for individual listeners showing THL at 4000 c p s plotted against the intensity of a 3-minute exposure to white noise The parameter is the time after the cessation of the noise The arrow in each panel indicates the intensity above which the 6-minute curve either levels off or declines

Under these conditions, examination of the data shown in Fig 2 suggests that for a given listener the curves for the three different times after the exposure can be superposed by shifting their positions along the intensity axis

In order to facilitate comparisons among the listeners, part of the data of Fig 2 are replotted in Fig 3 The upper panel shows the THLs 15 seconds after the exposure, and the lower panel shows the THLs 6 minutes after the ex-

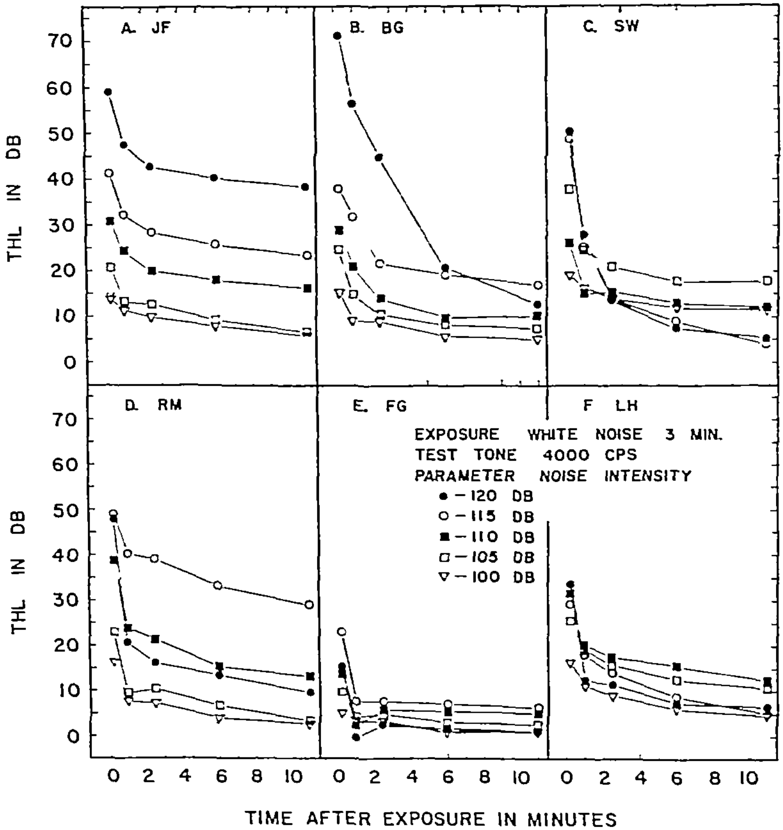

Fig 4 Recovery of the 4000 c.p s. threshold after a 3-minute exposure to white noise. Each panel shows the data for an individual listener The parameter is the over-all intensity of the noise.

covery curves after exposure to the "low" noise intensities are remarkably independent of the noise intensity Also, listener JF did not show a maximum in his curves for THL plotted against noise intensity (see Fig 2) The recovery curves for JF in panel A of Fig 4 all have much the same shape

The marked change in *rate* of recovery in the results of the experiment reported here cannot be explained readily by assuming that some protective mechanism of the ear simply reduced the effective stimulation of the inner ear during the duration of the exposure It would seem that such a mechanposure These curves have been "amputated" as suggested in the previous paragraph It can be seen that the shapes of the curves are highly similar for all listeners Inspection of these graphs suggests that the main difference among listeners is the position of the curve along the intensity axis Of course, this conjecture can be correct only for the THLs up to the intensity at which the inversion or leveling off occurs

An inversion or sharp deceleration in curves showing THL as a function of the intensity of the exposure stimulus will now be discussed With an exposure stimulus of about 120 db, Egan,[4] using white noise, and Davis, et al,[2 3] using pure tones, also found this effect Davis, et al, add that the intensity at which this "bend-over" occurred varied from listener to listener and for a single listener from day to day These investigators interpreted their results to mean that some protective mechanisms of the ear, such as a contraction of the intra-aural muscles or a change in the mode of vibration of the stapes, attenuates the effective stimulation of the inner ear Referring back to Fig 2 above, if one were to look at only one curve at a time, then the data would fit into the pattern described by Egan and by Davis, et al

The nature of the change that takes place after THL reaches a maximum can be best illustrated by plotting for each listener the family of recovery curves with the intensity of the noise as a parameter Fig 4 shows the data plotted in this way These are essentially the same data as shown in Fig 2, but the data for more times after the exposure and fewer intensities are given

The recovery curves for BG and RM given in panels B and D show an effect present in the data for all listeners with the exception of JF Recovery from the more intense exposures is so rapid that the recovery curve crosses the recovery curves for the less intense exposures This crossing of recovery curves can be noted also in the data of SW, FG, and LH This change in the rate of recovery is quite dramatic, as can be seen by examining the recovery curves before the "bend-over" is reached The shapes of the re-

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CLINICAL BONE CONDUCTION AUDIOMETRY AT THE FRONTAL BONE

(Abstract)*

R F Naunton,

University of Chicago Clinics,

Chicago, Ill

Our interest in clinical bone conduction audiometry stems directly from early tuning fork days when the value of comparisons between air conduction and bone conduction hearing was very well recognized The level of interest current 50 or more years ago is well illustrated by the fact that at that time Quix was able to quote well over 200 papers concerned with bone conduction hearing, and for the most part our interest has diminished very little since the advent and development of the electrical audiometer Some accept bone conduction audiometric test results at their face value, others emphasize their value and accuracy, and there are a few otologists and audiologists, perhaps the more discriminating, who have no confidence at all in such measurements, and who have little or nothing to do with them

The almost universal practice of carrying out bone conducism would reduce the early THLs as much as the THLs at the later times after the exposure

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SUMMARY OF RESULTS

1 The shape of the curve relating THL to intensity of the exposure stimulus is nearly the same at different times after the cessation of the noise The main effect of time after exposure is to shift the position of the curve along the intensity axis

2 The shape of the curve relating THL to noise intensity is nearly the same for all listeners The main difference among listeners appears to be the position of the curve along the intensity axis

3 For THL >15 db, the relationship between THL and noise intensity for the individual listener can be approximated by a straight line with a slope of about two

The above conclusions are qualified by the fact that a leveling off or maximum in the curves relating THL to noise intensity occurs for most listeners, once the noise intensity becomes as great as 110-120 db Individuals appear to differ with regard to the intensity at which this effect first occurs

With regard to individual differences in susceptibility to temporary hearing loss, the following hypothesis is tentatively proposed A given listener's position in a frequency distribution of THLs, when all listeners are exposed and tested under the same conditions, will depend upon two factors *1* the position of his curve (THL against noise intensity) along the intensity axis, and *2* the intensity at which this curve shows a leveling off or an inversion

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use of both air conduction and bone conduction receivers on the same ear

Other observations by Barany led to the conclusion that we may do better in clinical bone conduction tests if we place the bone conduction receiver on the frontal bone, inertia and cartilage conduction would thus be reduced or abolished, there would probably be less inter-subject variation in bony contour, and it is far simpler to apply a bone conduction receiver to the frontal bone than to the mastoid, and far easier to be sure of reproducing the test conditions as tests are repeated One distinct advantage of the frontal bone site is the ever-present reminder that the ears are being stimulated equally, and that masking is almost always required, moreover, while using a frontal bone conduction receiver the two ears may be covered by air conduction receivers, and masking tones may very conveniently be fed to either ear at will

One minor and readily overcome disadvantage of the frontal site is that at most test tone frequencies more power is required to reach the threshold of hearing than is required at the mastoid bone

The importance of the size of the frontal sinuses in bone conduction measurements of this type remains an uncertain quantity, but it is one that must be examined further

If we are to consider seriously the possibility of making bone conduction measurements at the frontal bone while our listeners wear a pair of air conduction receivers, we must learn a good deal more than is generally known at present concerning the occlusion effect in pathological ears We must in particular know whether cases with pathological hearing will show occlusion effects resembling those shown by the normal ear Such evidence as there is, suggests that the normal occlusion effect will be reduced in the case with a pathological middle ear by an amount equal to the magnitude of that ear's conduction deafness

In an attempt to gain further information on this and other related problems, about 500 ears were tested, audiometrically, some had visible middle ear changes of various types, some had otosclerosis, and some had neither visible changes nor tion tests with the receiver applied to the mastoid process of the tested ear is perhaps unfortunate, because it encourages the false notion that the opposite or untested ear remains in splendid isolation, separated from the test tone just as effectively as is recognized to be the case in air conduction tests, however, the inadequacy of bone conduction isolation has now been accepted, and the resulting and almost invariable need for masking is well recognized, but we still adhere to the mastoid process, a site with very little to recommend it

Barany, many years ago suggested, with clearly stated reasoning, that the mastoid process was far from being the best site of application for the bone conduction receiver in clinical tests All of our present measures of bone conduction hearing are confused to some extent by reflections of middle ear function, an inevitable result of inertia bone conduction hearing and other factors, of all the possible sites available for a bone conductor receiver, the mastoid process will give us the greatest confusion, because at this site inertia bone conduction is at a maximum Barany also pointed out that clinical bone conduction hearing will increase as the receiver is moved closer to or into contact with the cartilage of the external ear, another argument against the adequacy of the mastoid site There are numerous other disadvantages entailed in using the mastoid process, mastoids vary widely in tissue density and "the most sensitive spot of the mastoid" varies in position from individual to individual Otologists who have carried out bone conduction tests will agree that it is often impossible, using a double headset with an air conduction and a bone conduction receiver, to persuade the bone conduction vibrator to do more than perch precariously behind the listener's ear, and the choice of application site disappears when the receiver can be made to stay on the head in only one position Another difficulty encountered is reproduction of original test conditions, in terms of application site and pressure, as tests are repeated from time to time A final objection to the mastoid type of bone conduction test is that the tested ear must remain exposed to any air-borne ambient noise during the test, because our orthodox air conduction receivers are too large to permit the simultaneous

The points mentioned lead to the conclusion that clinical bone conduction audiometry, carried out with occluded ears and with a frontal bone conduction receiver, is well worth serious consideration Our orthodox techniques resemble efforts to compare the weights of a number of men, any of whom may be concealing 15 db of lead about their persons Occluded frontal bone tests will ensure that, whether "built-in occlusion effect" is present or absent, we derive a far less inaccurate measure of cochlear reserve

The observations described were made in the course of a series of small scale probes into the question of clinical bone conduction hearing The results suggest that well planned attacks on the problem are likely to be rewarding

PROPOSED AUDIOLOGY CENTRE OF THE NATIONAL CENTRE FOR THE DEAF IN INDIA

(Abstract)

C A AMESUR,
Bombay, India,
and
C SATYANARAYANA,*
Madras, India

For the past few years it has been the earnest endeavor of the Government of India of finding ways and means to quicken the pace of rehabilitation of the handicapped persons With this object in view, the Committee on Deafness was appointed in 1952, and the Deaf Seminar held in September, 1955, which was ably presided by Shri U A Basrurkar

Dr C A Amesur, who has published a paper on "Lip Reading" in I J O, October, 1950, and "Rehabilitation of the acoustically handicapped" in the I J O, December, 1952, was requested by the Ministry of Education to give a talk on "Recent Progress in the Treatment and Prevention of Ear otosclerosis A frontally applied bone conduction receiver was used throughout, and all the cases were tested in each of two ways first, bone conduction with unoccluded or open ears, and second, bone conduction while the ears were occluded with a pair of standard air conduction receivers Masking was used in adequate amount to separate the function of the two ears The differences between the unoccluded and the occluded bone conduction thresholds were accepted as occlusion effects, and it became clear that most of the cases with normal middle ears, whether deaf or otherwise, showed the expected occlusion effect of about 15 db at 250 and 500 c/s, a lesser occlusion effect at 1000 c/s, and no occlusion effect at 2000 and 4000 c/s

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*Stanley Medical College Madras India

It also became clear that the majority of the cases with middle ear changes showed no occlusion effects at *any* test tone frequency, irrespective of the size of the air conduction loss present One further observation was that at some test tone frequencies the cases with middle ear lesions and moderate air conduction hearing losses showed bone conduction thresholds better, on the average, than the unoccluded normal ears' thresholds In other words these observations demonstrated the presence, in cases of mild middle ear deafness, of what has been referred to for very many years as "prolonged bone conduction hearing" It should be added that the phenomenon has often been referred to as "the *illusion* of prolonged bone conduction"

It has been pointed out above that the cases with moderate middle ear deafness had better than normal bone conduction hearing, and that these same cases will show no further improvement in bone conduction hearing when their ears are occluded, but the normal ear's bone conduction hearing will improve when the ear is occluded and comes up to the level of the pathological cases with "prolonged bone conduction" There is, therefore, some justification for stating that the pathological middle ears are behaving as though they were in a permanently occluded state, a state the author has tentatively labelled "built-in-occlusion" This may be a misleading term, and comments must be limited to the observations that the effects are very similar in terms of frequency distribution and of magnitude false security In Denmark the purchase of hearing aids is based on tenders in order to stimulate competition The individual hearing aids are controlled by an "artificial ear" at the Hearing Center, the plotted frequency curves are filed, and the individual hearing aids registered on index cards so as to have detailed account of the commonest defects Based on this file of defects, standards are prepared for improvements in new types of hearing aids The fitting of the hearing aid is based on a close cooperation between engineers and physicians

The capricious problem in the matter of fitting hearing aids is training in the use of the apparatus It is of the greatest importance that the patients persevere for the first month until they have adapted themselves to the aid and its secondary noises All the patients are referred to courses of up to four hours' instruction, and more than 50 per cent of the patients are trained in lipreading, hearing training, and speech correction Through reports of the 63 teachers of patients with defective hearing, operating in the area of the Hearing Centers, we are able to check the correctness of the rehabilitation process Particularly difficult cases are referred, and admitted to the college for hard-of-hearing adults at Fredericia, a rather unique institution, unknown in most other countries The training of children is supervised by traveling teachers who visit the individual homes of the children about eight times a year When necessary, vocational guidance is instituted

A re-examination of the first 8,000 patients of the Hearing Center in Copenhagen showed that only 4 per cent of the patients failed to use their hearing aids The re-examination was based on questionnaires, inquiries of personal friends, and reports from the teachers The small figure should hence be considered reliable, and be taken as an indication of the method applied by the Hearing Center, and classification of the patients Seventeen per cent of the applicants are not provided with hearing aids, either because their deficiency is not sufficiently pronounced or because they suffer from types of defective hearing which are not remedied by hearing

Diseases" at the Deaf Seminar, published in I J O, December, 1955 The Seminar accepted his following resolutions

1 That a model Audiology Centre be set up by the Government of India,

2 That smaller audiological units should be attached to all teaching hospitals,

3 That rehabilitation of laryngectomized patients be undertaken

On October 5, 1955, Government of India established the National Advisory Council for the Education of the Handicapped (Resolution No F, 1-34-55, D-2, dated January 9, 1955), and nominated the author on that body

The Council, at its first meeting, held in October, 1955, in the Council Hall of the Lok Sabha, elected the author on its Standing Committee

The Co-author worked out the cost of such a centre, which the author placed before the Council, which accepted the same, on the following day The cost of construction and an appropriate annual budget will be discussed

The authors acknowledge their debt to many colleagues in Europe, the United Kingdom and the United States

DISCUSSION

H W EWERTSEN, Copenhagen, Denmark In Denmark we now have six years' experience with the State Hearing Rehabilitation Centres, of which there are three, in cooperation with a special children's clinic Every Danish inhabitant, with hearing troubles of chronic character, is allowed free admission to the rehabilitation program, including examination by otologist, acoustic evaluation by pure tone and speech audiometry, fitting of hearing aids, vocational guidance, teaching and follow-up

The experience of the Copenhagen Hearing Center shows beyond doubt the necessity of a current control of all hearing aids supplied to patients Official authorization based on a few selected specimens proved quite inadequate, providing a

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aids Persons, who on account of mental insufficiency are unable to manage the hearing aid, are not supplied

As compared with all other medical care, the audiological rehabilitation of the hard-of-hearing persons must be considered an inexpensive and efficient measure, which often totally changes the entire outlook on life of the patient

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W Lloyd Graunke, Knoxville, Tenn
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Barry J Anson, M D , and Theodore H Bast, M D

Repair and Consequences of Trauma to the Stapes and Oval Window in Experimental Animals
Richard J Bellucci, M D , and Dorothy Wolff, M D

The Action of the Sense Organ of the Cochlea, Particularly from the Point of View of Neurophysiology and the Excitation of Nerve Impulses Hallowell Davis, M D

Observations on Temporary Threshold Shift Resulting from Noise Exposure Aram Glorig, M D

Congenital Stapes Fixation Howard House, M D

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Merle Lawrence, M D

No Subject Assigned John R Lindsay, M D

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Ben Senturia, M D

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R S Silverman, Ph D , and Hallowell Davis, M D

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Film Recording of Esophageal Speech by Means of the Image Intensifier
Medical Division, North American Phillips Co , Inc

Technical and Electronic Field
Speaker from the Bell Telephone Laboratories

New Operation for Short Circuiting the Tracheal Air into the Pharynx........John J Conley, M D

Tuesday, May 20, 1958

Changing Trends in the Treatment of Sinusitis
Frederick T Hill, M D

Nasal Obstruction Produced by Deformities about the Lobule........Henry L Williams, M D

Carcinoma-in-situ of the Larynx a Ten-Year Study of its Histopathological Classification, Prognosis and Treatment........Alden H Miller, M D
and Russel Fisher, M D (By Invitation)

Bronchoscopic Findings in Tubercular Children
D E S Wishart, M D ,
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PRESENTATION OF INSTRUMENTS

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Paul G Moore, M D (By invitation),
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The Experimental Use of Homografts for Repair of the Cervical Trachea........Joel J Pressman, M D

The Origin of Distortion in Cochlear Fluid Motion
J Tonndorf, M D

Pressures of the Labyrinthine Fluids Measured with an Electromanometer and Potential Value of These Pressures
Francis L Weille, M D , and John Irwin, M D

The Differential Diagnosis of Meniere's Disease
Henry Williams, M D

PROGRAM OF THE AMERICAN LARYNGOLOGICAL ASSOCIATION

Fairmont Hotel, San Francisco, Calif , May 19-20, 1958

Ground Substance ....Eugene S Hopp, M D (By invitation)

Vocal Rest in Laryngeal Disease...... ..Melvin C Myerson, M D

Management of Chronic Laryngeal Stenosis
Paul H Holinger, M D

Evidence of Laryngeal Participation in Emotional Expression Its Relation to Hysterical Aphonia.
A C Furstenberg, M D

EXECUTIVE SESSION

Panel Discussion

AFTERNOON SESSION

REHABILITATION OF THE POST-LARYNGECTOMIZED PATIENT

John J Conley, M D , Moderator

Types of Clinical Cases and Their Resultant Laryngeal, Esophageal, Pharyngeal and Neck Deformities
Charles M Norris, M D

The Vocal Therapist Place and Contribution to the Rehabilitation Program.........Paul J Moses, M D (By invitation)

Specific Discussion of Failures Advanced and Difficult Technical Problems ....F Johnson Putney, M D

Psychological Factors Determining the Success or Failure of the Rehabilitation Program
Hayes A Newby, Ph D (By invitation)

SYMPOSIUM—*Modern Criteria for Diagnosis and Therapy of Malignant Disease in the Upper Respiratory Tract*

Moderator ....Jerome A Hilger, M D , St Paul, Minn

Panel ....Harold G Tabb, M D , New Orleans, La
Walter P Work, M D , San Francisco, Calif
John J Conley, M D , New York, N Y

Combined Laryngectomy and Neck Dissection (A Motion Picture) ....Eugene L Grandon, M D , Iowa City, Ia
(By invitation)
Edgar S Brintwall, M D , Iowa City, Ia
(By invitation)

An Objective Approach to the Complaint "A Lump in the Throat" ....G Arnold Henry, M D , Toronto, Canada

Friday, May 23, 1958

A Clinical Look at Progress in the Evaluation of Hearing Function ....Frederick R Guilford, M D , Houston, Texas

An Unusual Parotoid Swelling—Its Diagnosis and Treatment
Albert C Furstenberg, M D , Ann Arbor, Mich

The Motor Activity of the Cricopharyngeus Muscle—A Laboratory Study (Candidate's Thesis)
John A Kirchner, M D , New Haven, Conn

SYMPOSIUM—*Stapes Mobilization—Two Years Later*

Moderator ....Howard P House, M D , Los Angeles, Calif

Panel ....Merle Lawrence, Ph D , Ann Arbor, Mich
Philip E Meltzer, M D , Boston, Mass
John R Lindsay, M D , Chicago, Ill
Victor Goodhill, M D , Los Angeles, Calif
Samuel Rosen, M D , New York, N Y
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George E Shambaugh, M D , Chicago, Ill
Edmund P Fowler, Jr , M D , New York, N Y

PROGRAM OF THE AMERICAN LARYNGOLOGICAL, RHINOLOGICAL AND OTOLOGICAL SOCIETY, INC

Wednesday, May 21, 1958

The Relationship of Thyroid Carcinoma in Children and Irradiation of the Thymus in Infancy
Shirley H Baron, M D , San Francisco, Calif

Discussion ...Robert R Newell, M D , San Francisco, Calif
(By invitation)

Middle Ear Effusion—Systemic Factors
Francis W Davison, M D , Danville, Pa

Open Discussion

SYMPOSIUM—*Reconstructive Nasal Surgery*

Moderator...... .....Ronald W Taylor, M D , Vancouver, B C

Panel........ .. ..Russell I Williams, M D , Cheyenne, Wyo
Joseph H Ogura, M D , St Louis, Mo
Harold Owens, M D , Los Angeles, Calif

The Transseptal Intra-Nasal Dacryocystorhinostomy—A Neglected Operation (A Motion Picture)
E R V Anderson, M D , Los Angeles, Calif

Malformations and Anatomical Variations Seen in the Middle Ear During the Operation for Mobilization of the Stapes (Candidate's Thesis)
Jack V Hough, M D , Oklahoma City, Okla

Thursday, May 22, 1958

Soft Tissue Roentgenography of the Nasopharynx for Adenoids.............Joseph L Goodman, M D , New York, N Y

Open Discussion

An Operative Technique to Prevent the Need of Postoperative Care in Radical Mastoid Surgery
J H Thomas Rambo, M D , New York, N Y

Open Discussion

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THE

LARYNGOSCOPE.

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RHINOPLASTIC APPROACH FOR DERMOID CYSTS OF THE NASAL DORSUM

Report of Three Cases *

RALPH H RIGGS, M D ,

Shreveport, La

Reports of midline dermoid cysts of the nasal dorsum have appeared sporadically in the American literature since Birkett's report[1] in 1901 Although the condition is not considered rare, fewer than 75 cases have been reported The lesion is generally agreed to be congenital, and its development is explained on an embryologic basis [2-4]

The purpose of this paper is to present the cases of three patients with dermoid cysts of the nasal dorsum, on whom I have operated, and to discuss rhinoplastic procedures that may be helpful in such cases Previously described approaches to this problem include midline incisions,[3-9] horizontal incisions,[4, 10] elliptical incisions,[4] an incision along the side of the nose between the inner canthus and upper part of the nasal dorsum,[11] external incisions (no other description)[12, 13] external incisions, plus opening of the cyst into the nasal cavity,[11] external incision plus bilateral osteotomy,[4, 11] and intercartilaginous incision plus septal operation [14]

As far as I have been able to determine, there has been only one case reported in the American literature in which

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*Read at the Meeting of the Southern Section American Laryngological Rhinological and Otological Society Inc. January 25-26 1958 Memphis Tenn

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more space After removal of the cyst the nasal cavities were loosely packed to reposition the septal mucosa Pieces of autogenous nasal bone and bovine cartilage were used to help repair the defect The tissues were closed in layers and an adhesive dressing was put on the nose

On microscopic examination of a section of the cyst (see Fig 2) a cyst wall lined with stratified squamous epithelium was seen surrounding a slit like space containing desquamated squamous cells Hair follicles and sebaceous and sweat glands were present in the cyst wall At one level a foreign body inflammatory reaction had developed in an environment showing a number of sebaceous glands and hair follicles The microscopic diagnosis was dermoid cyst.

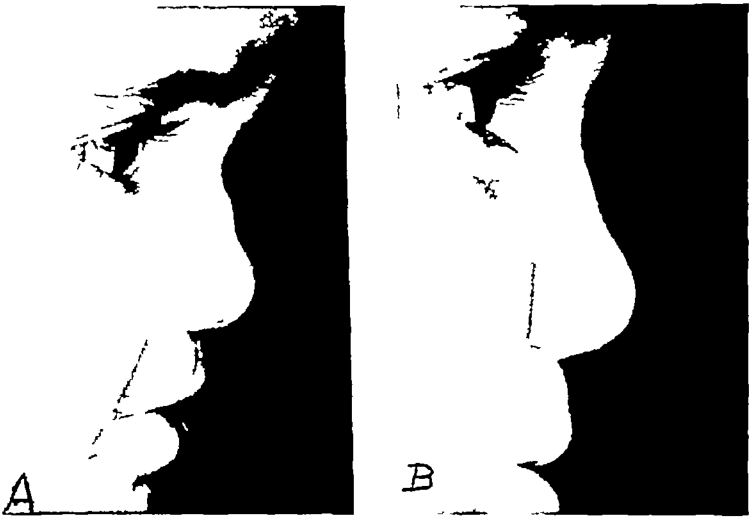

Fig 1 Case 1 A.—Note swelling over upper part of dorsum (1955) B—Five months after second operation (1957)

Comment After almost five years there is no evidence of recurrence of the cyst, however, the bovine cartilage became partly absorbed and was movable On June 16, 1957, intercartilaginous incisions were made, and the subcutaneous tissues were separated from the nasal framework The remainder of the bovine graft was removed, the bony parts were "freshened up," and multiple pieces of despeciated bone were inserted Fig 1-B, shows the patient five months after this operation

At this writing, seven months after the second operation, there seems to be no absorption of the inserted material In operation was not performed through an external incision over and along the side of the external nasal pyramid[14] Naturally, any case in which there is an opening, or sinus, along the midline will require an external incision to remove this area

Most of the reported cases have been from four large clinics,[4, 10-12] and more than one-half on the patients were operated upon by surgeons of another specialty The midline incision seems to be the most favored by the oto-rhinolaryngologist Approximately 30 per cent of the patients had had previous surgical treatment (including incision and drainage)

All authors agree that the entire cyst must be removed In the most recent article of Crawford and associates[10] total surgical removal is considered much more satisfactory than curettage, chemicals or the electric cautery, as have been used by some in the past They also believed that an attempt should be made to repair any defect present, however, later repair may also be necessary

REPORT OF CASES

Case 1 A white girl aged two years, had had a lump on her nose for the preceding six months Occasionally some drainage was noted near the tip of the nose The child's maternal aunt has a small swelling between the inner canthus and the nasion

On examination a rounded, semi fluctuant mass, measuring 4 × 4 mm was noted over the nasal dorsum (see Fig 1 A) It involved most of the bony vault and upper part of the cartilaginous vault At the tip of the nose in the midline was a small depression containing a hair that was perpendicular to the skin Slight pressure over the mass caused cheesy material to escape from the opening in the tip From palpation the impression was gained that the nasal bones were separated up to the frontal spine, and that much less bone was present than is normal for a child of two years On pediatric examination no other abnormalities or surgical contraindications were detected

On June 6 1953 after induction of endotracheal anesthesia a midline incision was made This was used because of the possible extension of the tumor and the smallness of the nose The mass above was exposed it lay between the nasal bones and upper third of the upper lateral cartilages and extended about 3 mm into the septum Below the cyst a stalk was followed to the tip where its opening to the outside was excised Another tract extended from the main body of the cyst upward and backward beneath the frontal spine to the region of the cribriform plate To be able to follow and visualize this tract some of the medial border of each remaining nasal bone had to be removed (this was saved to use in repair later) The nasal cavities were not entered at any time althoug the septal mucosa was reflected about 3 mm on each side to provide

Waters and lateral roentgenograms of the skull and facial bones were made A fairly well defined radiolucent shadow in the nasal bone was seen only in the lateral views.

On April 25 1955 after induction of endotracheal anesthesia incisions were made along the caudal margins of each lobular cartilage extending medialward into the anterior portion of the columella. After both lateral and medial crura were uncovered the soft tissues over the dorsum and along the side of the nose were undermined up to the nasion. The space in which to work was limited because of the small nose. It was therefore considered necessary to make an incision through the columella at its anterior extremity After mobilization of this area excellent exposure was provided to the whole dorsum of the nasal framework The cyst was separating the upper part of the upper lateral cartilages extending upward beneath the nasal bones and had caused some separation of their caudal ends It also extended along the dorsum of the bony and cartilaginous septum and this caused the thickening noted on intranasal examination. As dissection was carried out around the cyst, it was necessary to remove part of the mesiocaudal margin of each nasal bone to afford working space. The upper extremity extended to the posterior cephalic region of the nasal bones A small elliptical incision was made around the opening in the tip to remove the external opening of the caudal tract. This was closed with nylon sutures The bony defect was filled with the removed bone and some isogenous cartilage The incision in the columella was sutured with nylon A small amount of packing was placed in both nasal cavities and vestibules and an adhesive dressing was applied over the whole nose

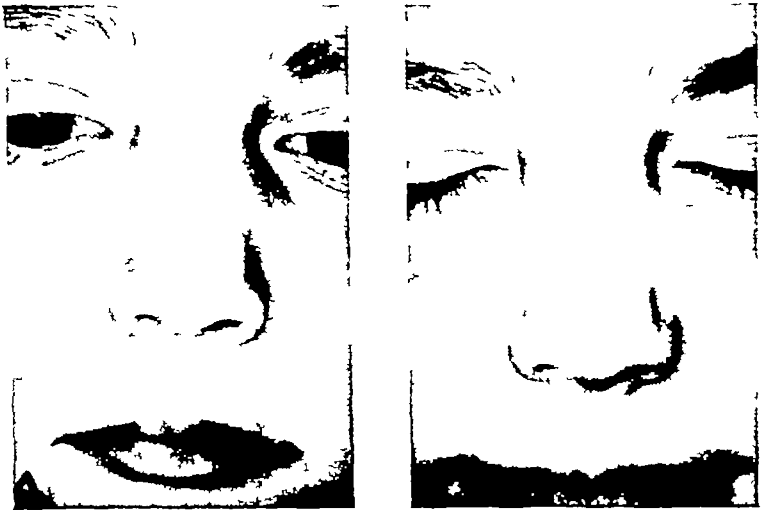

Fig 3 Case 2 A.—Preoperative view showing small pit opening at tip B—Photograph two-and-one-half years postoperatively

On microscopic examination of sections of the removed cyst fibrofatty tissue was seen containing an irregular cystic space lined with stratified such a case some substance has to be used to correct the defect Autogenous cancellous bone in the past has given the best results, but in such a young child, of course, it cannot be obtained If the grafts that were inserted become absorbed, some kind of graft will have to be employed, not only to relieve the deformity but also to help keep the soft tissues stretched so that eventually, if necessary, autogenous cancellous bone can be used

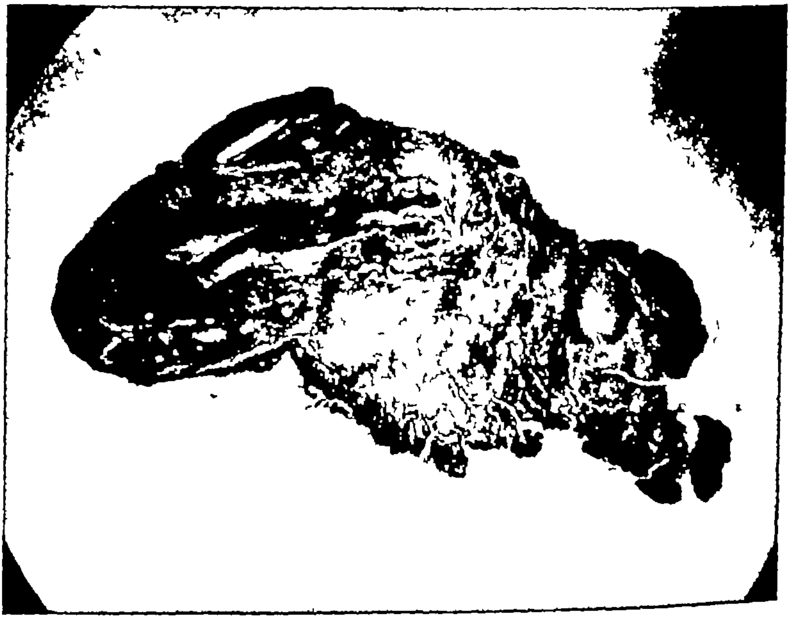

Fig 2 Case 1 Photomicrograph of dermoid cyst showing a cyst wall lined with stratified squamous epithelium surrounding a slit like space containing desquamated squamous cells Hair follicles and sebaceous and sweat glands are present in the cyst wall (X-20 H & E)

Case 2 A white girl five and a half years old had had drainage from *the tip of the nose since birth During the preceding year* this area had bled on several occasions after injury The child had always been nervous and restless while sleeping

On examination at the tip of the nose in the midline was noted a small depression that contained hair perpendicular to the skin (see Fig 3 A) With gentle pressure over the cartilaginous dorsum a thick cheesy material exuded On palpation the impression was gained that the cartilaginous dorsum was soft in the midline and that the caudal ends of the nasal bones were separated medially more than is normal Intranasal examination showed what was thought to be some thickness of the septum along both sides opposite the upper lateral cartilages bridge of his nose since birth and at least one hair was always present At times it became infected and drained what was thought to be pus

On examination a somewhat punched out area measuring 3 x 3 mm was seen on the nasal dorsum at the level of the caudal end of the nasal bones in the midline A few hairs were protruding (see Fig 5-A) no discharge could be expressed There was no external evidence of pathologic alterations below or above this area Intranasally the septum was deviated in its bony portion bilaterally

In lateral roentgenograms of the nose there was evidence of a radiolucent area about 0 5 cm wide extending from the anterior tip of the nasal bones posteriorly for about 2 cm where it was obscured by the overlying bones of the skull In the postero-anterior view were noted deviation and definite widening of the nasal septum in its antero-superior portion where again there was a faint radiolucent area There was no evidence of destruction of bone The changes were suggestive of a lesion in the antero-superior portion of the nose, causing some erosion of the nasal bones and occupying and causing some widening of the septum anteriorly Iodized oil (Iodochoral®) was injected into the sinus tract' and another roentgenogram was made (see Fig 6) The tract extended from the opening in the anterior portion of the nose posteriorly for about 4 cm where it was blocked apparently by a soft tissue mass

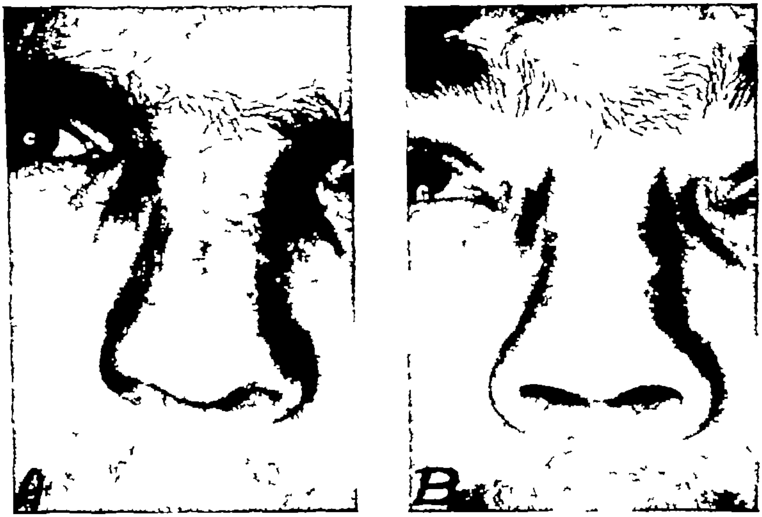

Fig 5 Case 3 A—Preoperative photograph shows hairs in the depression B—Photograph twenty-three months postoperatively

On Feb 22 1956 with use of a local anesthetic the septum was opened through a left hemi transfixion incision and the left septal mucosa was elevated back to the bony deviation The cartilaginous septum was separated from the bony septum and the mucosa over the right and left bony septum was elevated A bulging of the bony septum previously described as a deviation was opened and found to contain a cystic mass This squamous epithelium around which were rudimentary sebaceous glands and hair follicles containing hair shafts Several shafts were within the lumen of the cyst Adjacent to the cyst in one section was a foreign body reaction about hair shafts, due apparently to rupture of the cyst at one point not disclosed in these sections The microscopic diagnosis was dermoid cyst (see Fig 4)

Comment In this case the described approach was adequate, and no deformity has resulted after three years One week after the initial dressing the child's family reported that she was not so nervous as before operation, that she was breathing well through her nose for the first time in her life, and that she was able to sleep without making noises, having nightmares and pulling off the cover During the ensuing three years this result has persisted The parents also admit that they, too, have been somewhat rehabilitated, owing to what they call having a normal child

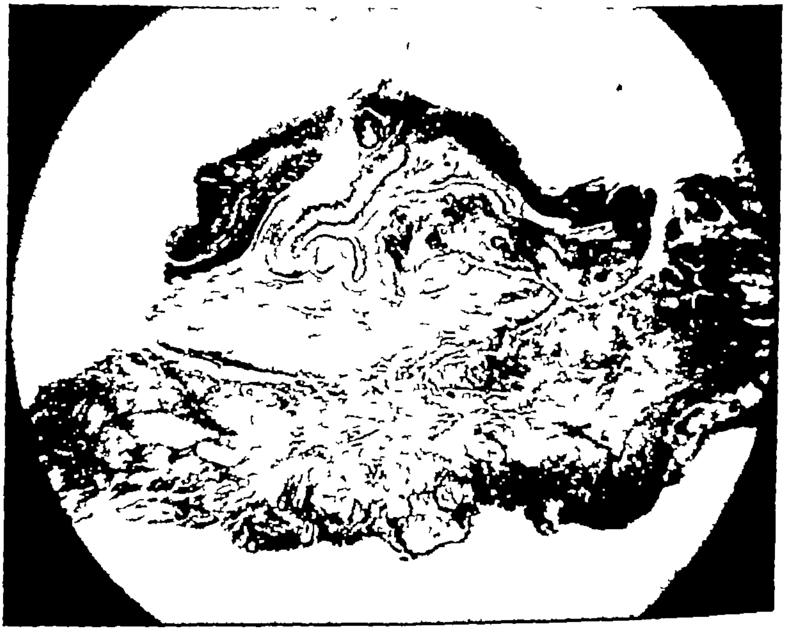

Fig 4 Photomicrograph of dermoid cyst in Case 2 showing fibrofatty tissue containing an irregular cystic space lined with stratified squamous epithelium around which are rudimentary sebaceous glands and hair follicles containing hair shafts (× 20 H & E)

Case 3 A white man 29 years of age had had a 'deformity on the narrowed as it was uncovered posteriorly and extended almost to the face of the sphenoid (see Fig 7) The cyst uncovered in the bony septum was opened and contained a cheesy material An elliptical incision was made around the external opening and the soft tissues were undermined The stalk was dissected down between nasal bones and upper lateral cartilages and then followed into the exposed area in the septal space All attachments were severed and it was removed To correct the deformity between the nasal bones and also to help narrow an abnormally wide bony vault bilateral osteotomy and infracture were performed Bone was replaced between the septal flaps and the incision in the septum was closed The external incision was closed in layers after some autogenous bone and septal cartilage had been placed over the dorsum Adhesive and stent dressing was applied

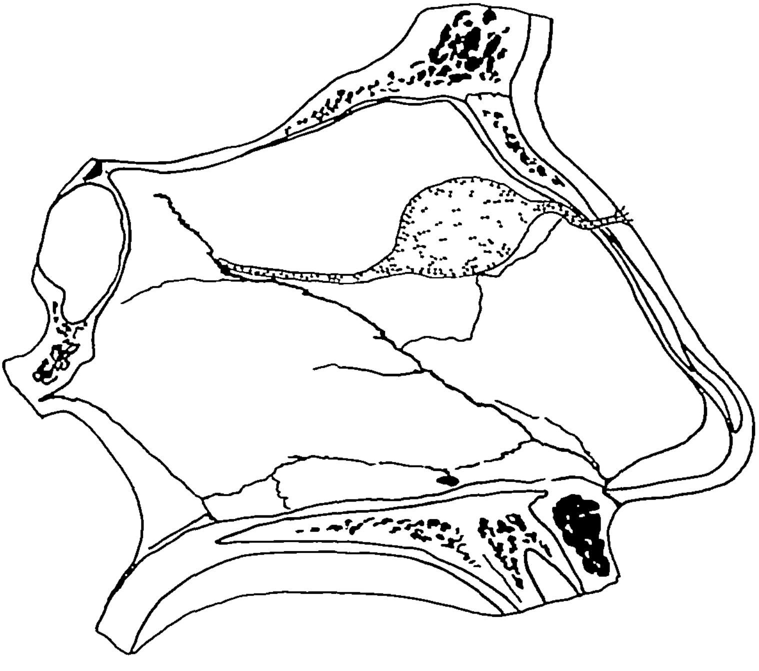

Fig 7 Diagram of extension of cyst in Case 3

On microscopic examination of sections of the removed specimen a channel or cavity lined with stratified squamous epithelium containing epithelial debris and blood was seen (see Fig 8) In the wall surrounding the cyst numerous hair follicles and sebaceous and sweat glands were present. The microscopic diagnosis was dermoid cyst

Comment All of the cyst was removed through the septal exposure except, of course, the external portion Two other cases of cysts of the septum[11 14] have been reported, but they

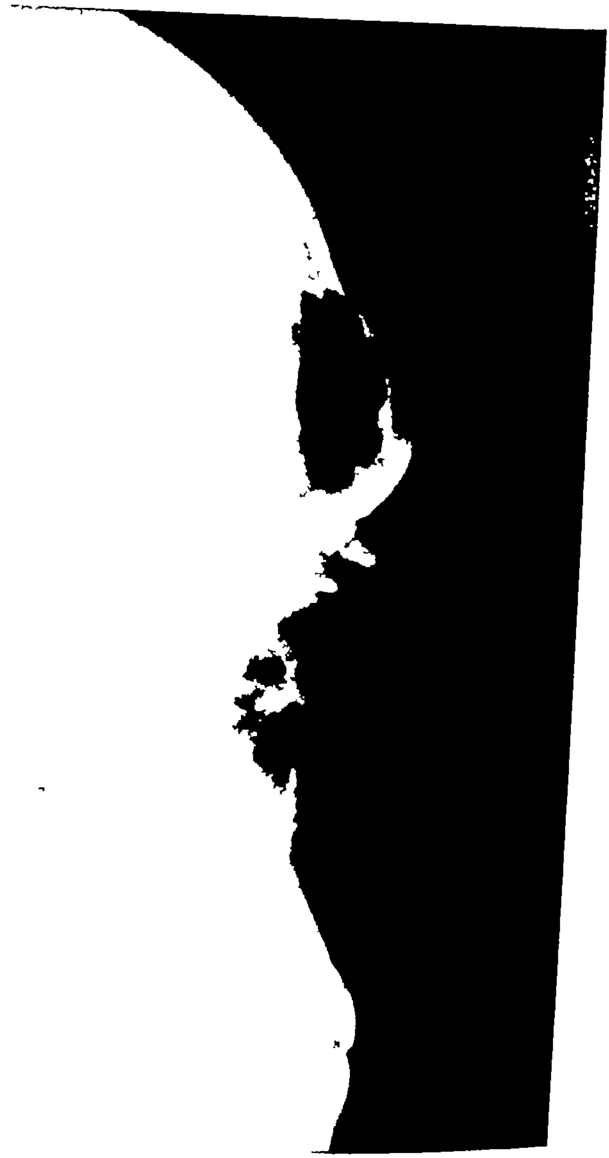

Fig 6 Roentgenogram made after injection of iodized oil The posterior extension is not visualized because the contents of the cyst obstructed its flow

pathologic alterations found Intercartilaginous incisions will provide good exposure up to and including the frontal spine One may also remove a mid-dorsal cyst and inspect the area posterior to the nasal bones and frontal spine if the cyst extends into this area It is also possible to go down into the nasal septum through the upper lateral cartilages and combine this procedure with a septum operation for complete removal of a cyst This was part of the procedure described by Juers,[14] and was used in Case 3 herein reported

If the stalk comes down to the tip, another approach is possibly better Incisions may be made along the caudal margins of both lobular cartilages (the slot incision described by Cottle[15]) extending down along the columella The tissues external to the cartilage are uncovered, and the surgeon, continuing upward, may uncover the whole pyramid By adequate and careful dissection the pathologic alterations can be visualized and removed providing the nose is not too small In an extremely small nose, to obtain more working space, the columella can be severed at its anterior extremity, as was done in Case 2, this leaves only a minimal scar

Another helpful procedure is osteotomy Its use has been reported previously in two cases[4] This helps, in that the bony dorsum may be narrowed, it also helps to correct a deformity after part of the bone has been removed and helps insure formation of a good roof over the bony vault[16] This procedure was used in Case 3

A secondary operation to correct a deformity created by the cyst and its removal is essential in some cases[10] Here again rhinoplastic procedures are invaluable, since most of these probably require attention to the bony dorsum This area is easily reached through the intercartilaginous incisions Such a procedure was used in a secondary operation in Case 1, in which the remainder of an old graft was removed, and some other grafts were reinserted It is also possible to work in this area through the slot incisions should additional procedures need to be performed on the cartilages of the lobule were both located in the septal cartilage, also in the cases reviewed only two osteotomies[4,11] had been performed and they were not associated with the septal cases

At this writing, practically two years postoperatively, there is no evidence of recurrence of the cyst A serious psychologic problem has become greatly improved

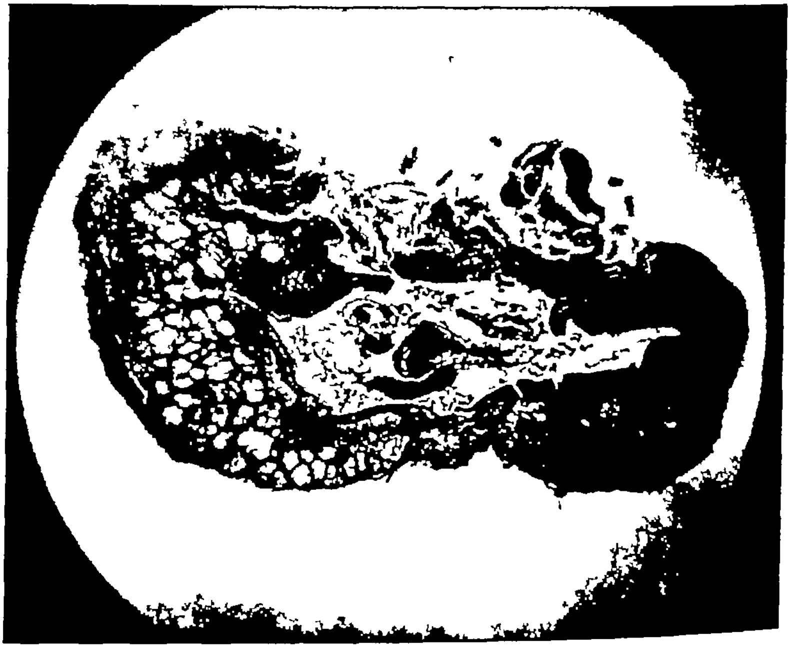

Fig 8 Photomicrograph of dermoid cyst in Case 3 showing a cavity lined with stratified squamous epithelium containing epithelial debris and blood In the wall surrounding the cyst numerous hair follicles and sebaceous and sweat glands are present (X-20 H & E)

DISCUSSION

No routine operative procedure can be employed in these cases because the pathologic process varies Even though the incision over the nasal dorsum does not cause a bad deformity, there is a scar In patients who have only the small "pit opening" at the tip, and those who have a mass along the junction of the upper lateral cartilages and the nasal bones, the possibility of using a rhinoplastic procedure is real Naturally the procedure used depends upon the diagnosis and

PERNASAL TRANSSPHENOIDAL YTTRIUM IMPLANT OF THE HYPOPHYSIS *†‡

W M S IRONSIDE, M D ,
(By Invitation),
and
ROBERT D MOSELEY, JR., M D ,
(By Invitation),
Chicago, Ill

In 1953, Luft and Olivecrona demonstrated the beneficial results that could be obtained with hypophysectomy in certain cases of advanced cancer After much experience it now appears that only the hormone dependent cancers of the breast and prostate are likely to benefit

As a result of the interest in hypophysectomy, numerous routes to the gland have been used, and methods of excision or destruction employed The aim, of course, is to devise a simple operation which will cause minimal distress to the patient, as many of these coming to this type of surgery are severely debilitated, at the same time it is necessary to insure effective destruction or removal of the gland

It is as well to recall some of the routes which have been used in the past to reach the hypophysis Although the transcranial route was one of the first to be used, the mortality rate was so high that by the end of the first decade of this Century interest was being developed in the nasal routes, but even with the transseptal,[2] lateral rhinotomy,[3] sublabial routes[4 5 6] and their numerous modifications,[7 8 9] the mortality rate in some series ran as high as 30 per cent By the 1930's the great advance in neurosurgical techniques, and the need

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†From the Departments of Otolaryngology and Radiology The University of Chicago

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SUMMARY

Three cases of midline dermoid cysts of the nasal dorsum have been presented Attention is called to the feasibility of using rhinoplastic procedures in applicable cases with the idea of leaving less visible postoperative defects

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a source of Gamma rays, in the form of two tubes by the pernasal transsphenoidal route with the assistance of a complicated head holder and needle director The procedure is controlled by intermittent radiography Radon was used because Pattison and Swan[14] in 1933 successfully treated a case of basophil adenoma of the pituitary by introducing two radon tubes into the sella turcica through the transcranial route Forrest found that the Gamma irradiation required to destroy the pituitary also affected surrounding structures such as the optic nerves, therefore, yttrium 90 with its high activity over a short radius is now being used

From the experimental work of Marinelli[15] it was considered that complete destruction was more likely to follow the implant of multiple discrete sources, 1 mm by 2 mm of yttrium, rather than the two larger sources, 2 mm by 6 mm, as used by Forrest, however, it was obvious that the nasal route held many advantages, the most important of which was the lower mortality rate, and adequate local anesthesia was considered sufficient to perform the nasal operation, a considerable advantage when dealing with these rather debilitated patients

It was felt that only under direct vision could the needle be directed through the nose to the anterior wall of the sphenoid sinus without injuring the nasal mucosa, and that only with the assistance of image intensifiers (Muller Surgex units with Phillips intensifier tubes) could multiple yttrium beads be deposited with any degree of accuracy throughout the pituitary gland The image intensifiers permit continuous fluoroscopic guidance throughout the procedure without exceeding the permissible exposure dose to the surgeon

The method evolved is as follows Under premedication of Nembutal 180 mgm, given two hours, and Demerol 100 mgm, given one hour before operation, the patient is brought to the operating room and very carefully positioned on the table with the occiput low in a modified Rose's position (see Fig 1) The reason for this position is to allow the axial image intensifier to be brought into place This positioning must be done with great care and gentleness in those patients with to remove totally, rather than partially, tumors involving this gland, the transcranial approach became once more the route of choice With the advent of the sulphanamides and antibiotics the mortality rate of this procedure steadily declined That this route was used by Luft and Olivecrona for excision of the gland in their pioneer work is not surprising

The report of Forrest and Peebles Brown[5] in 1955 renewed interest in the nasal route, and numerous modifications have been devised, but these routes are used mainly for the introduction of radioactive compounds rather than for surgical excision of the gland

Regarding destruction of the gland, probably the greatest experience has been with surgical excision, however, an increasing number of cases are being subjected to procedures in which the gland is necrotized by implanting radioisotopes External radiation methods, such as proton beam therapy, are at present in an experimental stage, and experience with them is very limited

The method devised is based mainly on the work of two groups one at the University of Chicago, the other at the University of Glasgow

Rasmussen, Harper and Kennedy,[11] of the University of Chicago, in 1953 suggested that yttrium 90, a pure Beta emitter, if implanted in the form of multiple discrete beads, described by Kisieleski[12] in 1950, could effectively destroy the hypophysis The transcranial route was used for placement of the beads, and in practice it has become obvious that even though the gland is under direct vision at the time of operation, accurate deposition of the beads is exceedingly difficult Unfortunately, due to the very nature of the operation, it is difficult to obtain a field free of metal impedimenta and to position the patient's head, so that the use of continuous radiologic control is practical, furthermore, the operation is attended by the usual mortality rate, associated with such a neurosurgical procedure under general anesthetic

Forrest[13] and his associates, of the University of Glasgow, reported in 1956 their results obtained by implanting radon, to the anterior wall of the sphenoid sinus Here the position of the tip and direction of the needle is checked by the intensifiers in both the axial and lateral views before the tip of the needle is advanced into the sphenoid sinus Into the sinus in instilled 1 5 cc of a penicillin topical thrombin solution, each cc of which contains 10,000 U of penicillin and 200 U of thrombin Under continuous guidance the needle

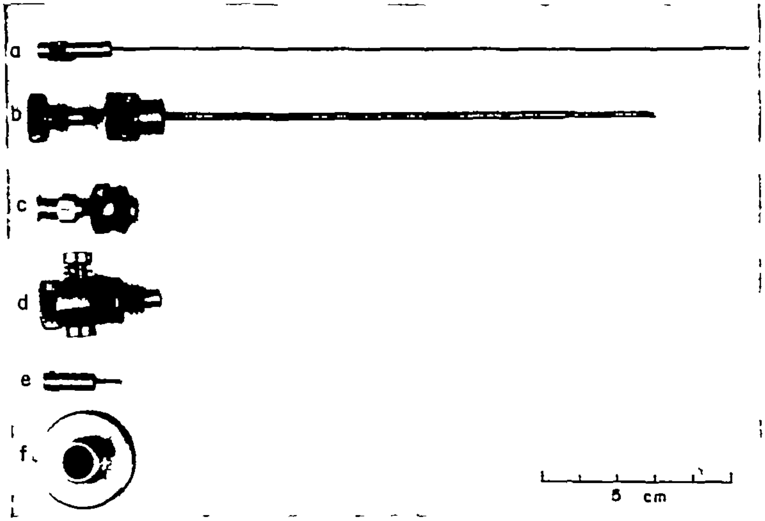

Fig 2 Special instruments for introducing yttrium beads a Stillette which passes through cartridge (c) and cannula (b) b trocar and cannula (17 gauge) c adapter for connecting syringe to cannula (b) during installation of penicillin thrombin solution d cartridge when mounted on stand (f) bead dropped into left end and pushed home with cartridge pin (e) while spring on transverse cylinder is compressed on releasing spring bead is trapped in cylinder quartz window permits observation of bead on its way through cartridge when stillette (a) is introduced e cartridge pin f stand for cartridge during loading

is advanced into the medial portion of the left half of the pituitary A posterior bead is deposited before withdrawing the tip a few mm and depositing an anterior bead The tip of the needle is then withdrawn into the sphenoid sinus and the needle angled laterally before being advanced once more into the gland Again a posterior and an anterior bead are deposited, and this time in the lateral portion of the left half of the gland Similar maneuvers are carried out on the right side (see Fig 3) spinal metastases, as any extreme degree of cervical extension will cause pain

Local anesthesia is then induced with cocaine, 5 per cent, by instilling 0 5 cc into each nostril with the head in three positions first with the head turned to the left, then to the right and finally in the midline Occasionally when the optimum position of the head and neck cannot be obtained the anesthesia is supplemented with a Sluder block (see Fig 1)

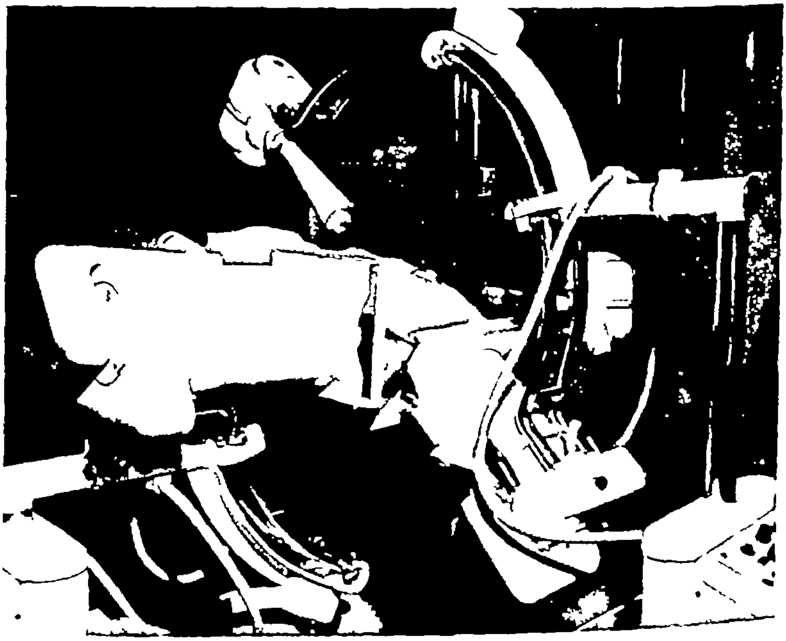

Fig 1 The patient in position on the table with the neck and head extended Image intensifiers are draped during operations

At this stage the face is prepared and drapes applied The two intensifiers are also draped and brought into position The yttrium beads, 1 mm by 2 mm, with an activity of approximately 1 mc, are then loaded into the cartridges under water One cm of water gives adequate shielding from the irradiation of these beads

The strengthened 17 gauge needle (see Fig 2) is then passed into the left nostril and guided under direct vision ment has not been started until signs of hypothyroidism develop, and this does not occur for at least two months postoperatively

MATERIAL

Although some 40 of these operations have now been carried out since June, 1957, only the first 26 will be reviewed, for at least two months are required to determine the effects of the procedure It is as well to point out at this stage that these cases were unselected, insofar as no consideration was given to the age and general condition of the patient, the type of the primary tumor or site of metastases and previous treatment received by the patient They were all considered to be unlikely to benefit from further surgery, radiotherapy or endocrine therapy, furthermore, the early operations were performed on patients who were in a very advanced, or even terminal stage of metastatic disease

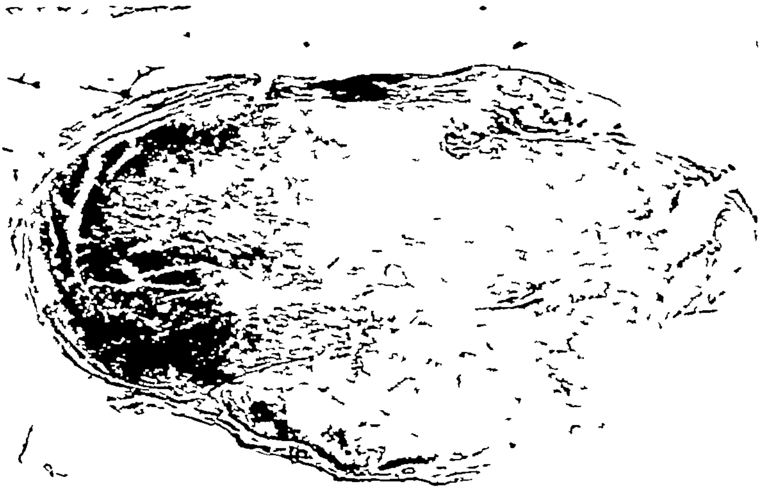

Fig 4 H and E. X 9 Pituitary obtained 15 days postoperatively from Case 1 showing almost total destruction

Generally eight beads are implanted, but as many as 11 and as few as six have been used Variations in the size of the sella and the accuracy of deposition of individual beads determines the total number deposited Variations in the position of the nasal and sphenoidal septum can be an inconvenience, but do not prevent an adequate implant Serial sectioning of the few pituitaries obtained at autopsy have revealed that an average of better than 90 per cent destruction has been obtained by this method (see Figs 4, 5)

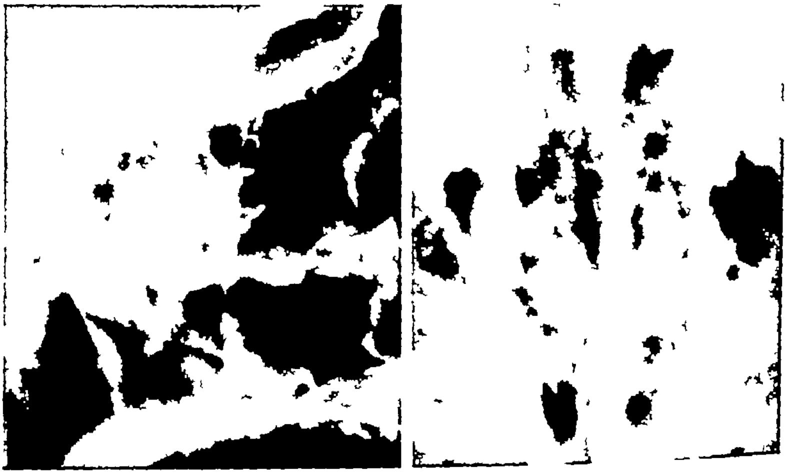

Fig 3 Implant obtained in Case 1 Lateral and axial views

Even severely debilitated patients stand the outlined procedure very well On two occasions, however, it has been necessary to give an additional 50 mgm of Demerol intravenously while the patient was on the table Only one patient was deemed unfit for operation, when she became drowsy and confused on the day tentatively planned for operation, she died nine days later

MAINTENANCE

All patients subjected to this procedure have required a maintenance dose of Cortisone, on the average this has been 50 mgm daily Pitressin tannate has been administered to those patients developing diabetes insipidus Thyroid replace-with a IVth nerve paralysis This is embarrassing for the patient, due to the drooping of the lid, but is no real handicap Two developed a temporary VIth nerve paralysis, which was rather distressing, due to the double vision which resulted One case of IIIrd nerve paralysis has started to clear after being present for two months

Examination of pituitaries obtained at autopsy have confirmed the suspicion that these paralyses arise from placing beads too far laterally The technique has been modified accordingly Surgical trauma at the time of operation plays no part in this complication, as the onset of paralysis is from the third to the sixtieth day

TABLE I

Complications in 26 Operations

Extra-ocular N palsies	10
Cerebrospinal rhinorrhea	4
Meningitis	2
Anesthesia of face	1

Using this route it was expected that cerebrospinal rhinorrhea might present—it has occurred in four patients In two patients it lasted for a number of months One was the patient already mentioned, who was suspected of having died from meningitis two months postoperatively The other was a man who had metastatic carcinoma of the prostate The rhinorrhea lasted two-and-a-half months, but the patient has now returned to work The two other cases of rhinorrhea were of a very temporary nature

Starting with the twentieth case topical thrombin has been injected into both sphenoid sinuses, with penicillin, at the time of operation, as indicated It is interesting that all these cases of rhinorrhea occurred within the first 14 operations, but this complication still occurs In the last 26 cases, two have developed temporary rhinorrhea

Meningitis was encountered twice first, in the patient who is suspected of having died from this complication, and the other, in a patient who against advice blew her nose

MORTALITY

Of the 26 cases under review there were no deaths directly due to the procedure One patient died two months postoperatively, and from the doctor's account of the terminal stage death probably resulted from meningitis Unfortunately, autopsy was not obtained This patient had developed a permanent cerebrospinal rhinorrhea two weeks postoperatively, and although she returned to the hospital it was decided that she was unfit to undergo transcranial closure of the defect, and was sent home again This indicates rather well the "poor risk" cases that stand the procedure so satisfactorily

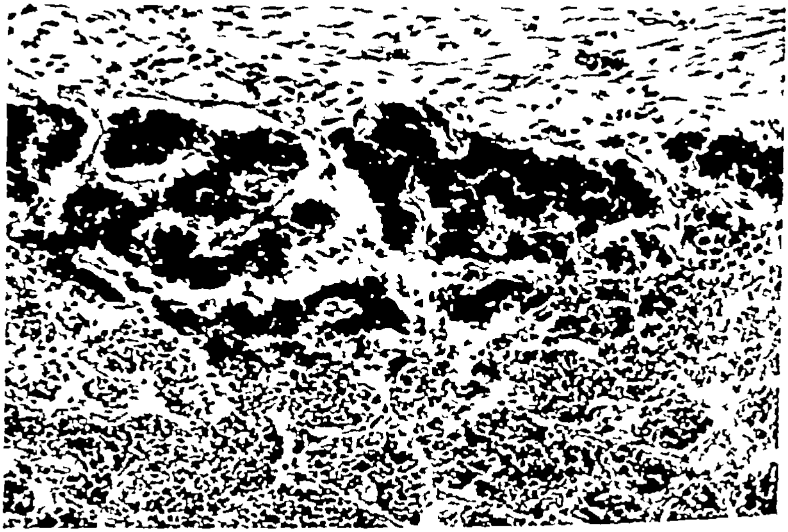

Fig 5 H and E × 150 of surviving cells note sharp line between surviving and necrotized cells

COMPLICATIONS

Thirteen out of 26 patients developed one or more of these complications

By far the most frequent complication, ocular nerve paralysis, developed in no less than 10 patients Eight suffered from a IIIrd nerve paralysis, either alone or in combination impairment, frontal lobe or hypothalamic damage, or brain abscess formation such as have been reported in other series

RESULTS

Of these 26 patients 21 had a primary lesion of the breast, four of the prostate and one of the ovary

TABLE II

Operations Performed

Performed for Metastatic Carcinoma of Breast (F—20 M—1)	21
Performed for Metastatic Carcinoma of Prostate	4
Performed for Metastatic Carcinoma of Ovary	1
Total	26

CANCER OF THE BREAST

The 21 cases of metastatic cancer of the breast consisted of 20 females and one male

TABLE III

Carcinoma of the Breast

Surviving—	
Unchanged	5
Improved	10
Dead—	
Unchanged	5
Improved	1
Total	21

Eleven appared to benefit from the operation

The estimation of the result of the operation is based on clinical observations such as cessation of vomiting, increase in appetite, weight gain, changes in size of cutaneous or subcutaneous lesions and X-ray studies of metastatic lesions Symptomatically, relief of pain has been the most dramatic feature of those gaining benefit from the procedure, however, only four have shown a true regression with sclerosis of esteolytic deposits, etc (see Figs 6, 7, 8) vigorously She suffered a temporary leak of cerebrospinal fluid and developed meningitis This responded to antibiotic therapy and the rhinorrhea ceased

During two procedures pellets were misplaced In one it is assumed that they entered the cranial portion of the left carotid and were whipped into its branches, two settling in the distribution of the middle cerebral of the same side, and another entered the circle of Willis, crossed to the other side and came to rest in the distribution of the anterior cerebral artery There were no after effects

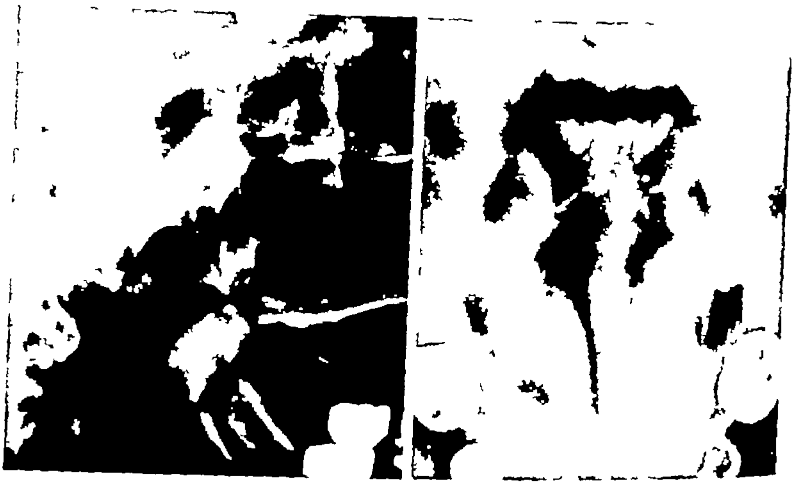

Fig 6 Lateral and axial views of implant obtained in Case 9

In the other case a pellet came to lie at the right petrous apex As a consequence of this the patient has developed a mild sensory loss on the right side of the face in the distribution of the ophthalmic and maxillary divisions of the Vth nerve

Although the complication rate in this series has been fairly high it can be reduced with experience This is evidenced by the absence of any complications following operation in the last ten patients subjected to this procedure since December 1, 1957

There have been no instances of anosmia, visual field

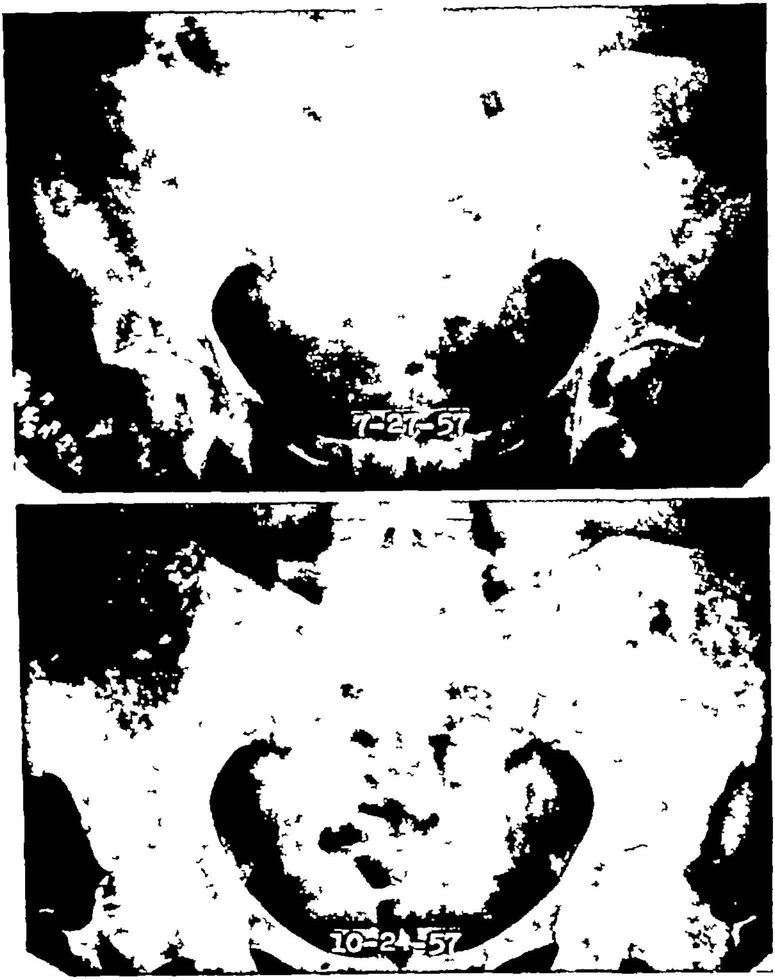

Fig 8 X-rays of pelvis before and 10 weeks after operation in Case 9

CARCINOMA OF THE PROSTATE

All four patients showed improvement after yttrium implant This was evidenced by return of appetite, disappearance of bone pain, resumption of ambulation or return of normal urinary function

The patient who had metastatic carcinoma of the ovary did not gain any benefit from the operation

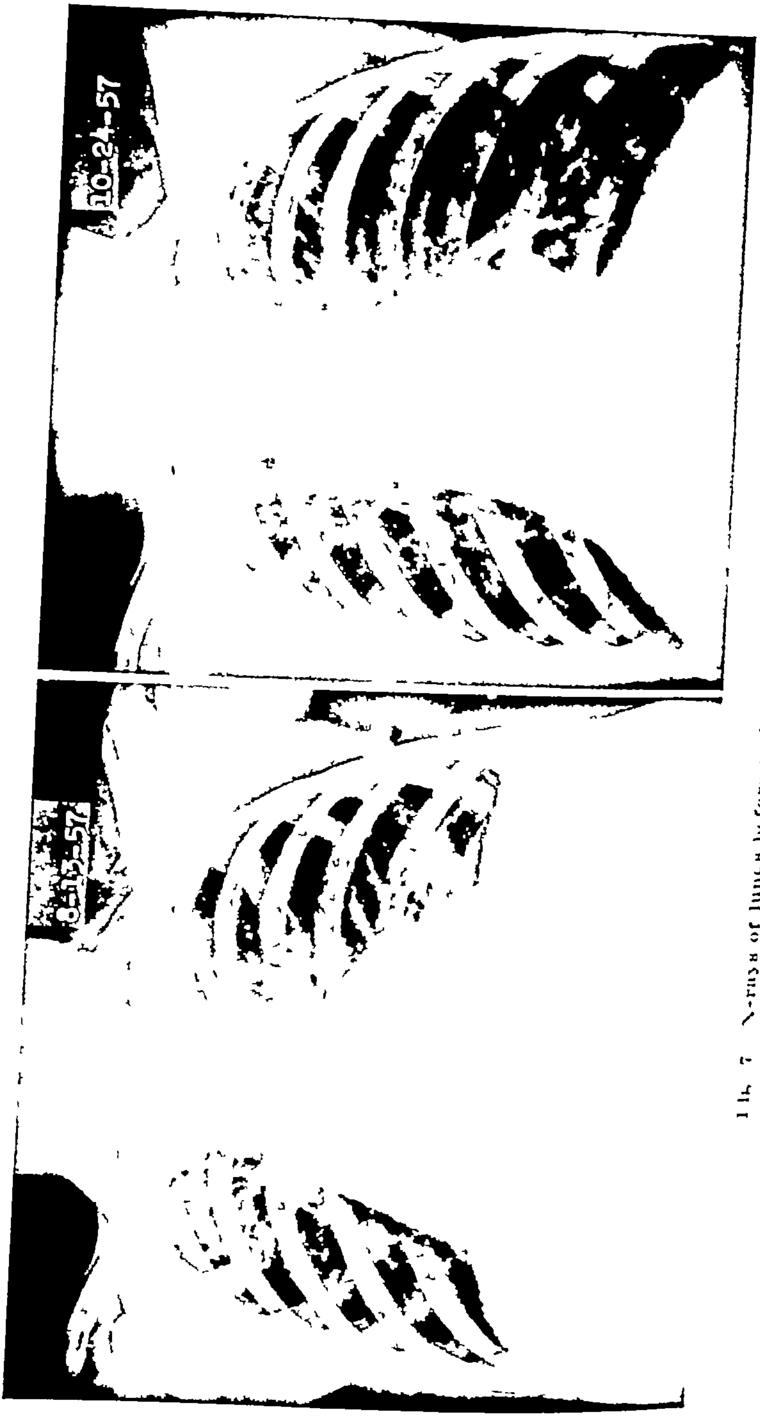

FIG. 7. X-rays of lungs before and 10 weeks after

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REHABILITATION OF THE LARYNGECTOMIZED

The University of Texas Postgraduate School of Medicine and the Houston Speech and Hearing Center will present the second training course in "The Rehabilitation of the Laryngectomized" from June 9 through 20, 1958

The course this year will be altered in several ways as a result of experience gained from last year's presentation and will cover Vocational Adjustment, Anatomy of the Speech Mechanism, Normal Speech and Voice Production, Esophageal Speech and Voice, Laryngeal Surgery, Radiation Therapy, Facts about Cancer and Techniques in Teaching Esophageal Speech

The general presentation will combine both the clinical and didactic approach

Applications for Traineeships, which are limited in number, should be made as soon as possible, and will not be considered after May 19, 1958

Inquiries concerning this course should be directed to The University of Texas, Postgraduate School of Medicine, 410 Jesse Jones Library Building, Texas Medical Center, Houston 25, Texas

CONCLUSION

As has been stated, virtually all patients referred with advanced cancer of the breast and prostate have been accepted for this procedure It is felt that with better selection of cases the percentage of patients benefiting will increase, and with more experience and knowledge gained from autopsy studies the complication rate will continue to decrease

SUMMARY

Routes to the pituitary and methods of destruction are reviewed

A simple method of yttrium implant of the hypophysis with continuous fluoroscopic control and under local anesthesia is outlined

The results, obtained by 26 such procedures performed on patients suffering from advanced cancer are presented [*]

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[*] We acknowledge our indebtedness to Dr J P Evans for his assistance and advice and to Dr P V Harper Jr for arranging the supply of yttrium 90

fore, tried maneuvers in which a rocking force was applied through the incus and incudo-stapedial joint This resulted in a greater success rate, but crural fractures were still too frequent, and it soon became obvious that many fixed footplates could not be mobilized by forces exerted through the crura The procedure passed rapidly, therefore, into the next stage in the evolution of methods to mobilize the footplate, this being the direct method by which cutting, prying, hammering, needling, chiseling and drilling techniques are used directly on the margins of the footplate Among the first to use the direct method extensively in this country were House[2] and Goodhill,[3] who needled the margins of the footplate, whereas in Europe, Heermann[4] of Essen reported success with chisels, and Meurman[5] of Helsinki with serrated knives More recently, Portmann[6] of France and Shea[7] in this country have utilized a micro-drill to lyse otosclerotic foci, but their experiences are, as yet, not adequate to predict whether the method will enhance existing techniques

I (H F S) visited Professor Zollner at the University of Freiburg in November, 1956, and saw him demonstrate the method of mobilizing the stapes with the chisels of Heermann I used these instruments on a series of patients, and when Heermann attended the International Congress of Otolaryngology in Washington, D C , in May, 1957, I had an opportunity of discussing the method further with him Since that time, I have been using the chisels exclusively in all our mobilization operations The early results are good enough to justify enthusiasm for the method, and the main purpose of this paper is to describe the technique and to present our experiences with it We will also show our results with previous techniques

GENERAL INFORMATION

Our indications for surgery have been the same from the beginning, *i e*, any patient with a clinical picture of otosclerosis who has a bilateral air conduction hearing loss averaging over 30 db for the speech frequencies (500, 1000, 2000), with no restrictions as to age or level of bone conduction thresholds Patients who have no chance of improving

RESULTS WITH THE CHISELS IN STAPES MOBILIZATION[*]

HAROLD F SCHUKNECHT, M D ,[†]
A BRUCE GRAHAM, Ph D ,[**]
and
MARY ROSE COSTELLO, Ph D [**]
Detroit, Mich

When the stapes mobilization operation was first described by Rosen in 1954[1] there were many skeptics Some said that the operation was doomed to failure because labyrinthitis was apt to ensue in many patients, some felt certain that early re-ankylosis would occur, and others said that the operation had been tried before and discarded because of poor results Time has shown that this early skepticism was not justified, for the greater proportion of successfully mobilized patients have not experienced re-ankylosis, and very few have had serious complications We must attribute much of the success of the stapes mobilization operation to the invention of the operating microscope with built-in light, which finally has provided adequate visualization for the otologists, and to the development of antibiotics which are used to reduce the incidence of post-operative infection

The technique of mobilization has undergone a rapid transition from the original Rosen method to direct footplate techniques which have resulted in a higher percentage of successful results The original technique described by Rosen consisted of applying pressure to the neck of the stapes so as to mobilize the footplate by tilting it in the oval window Many otologists, including Rosen, were dissatisfied with the results because of the high incidence of crural fractures and, there-

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[*] Read at the meeting of the Middle Section American Laryngological Rhinological and Otological Society Inc Chicago Ill Jan 13-14 1958

[†] Associate Surgeon Division of Otolaryngology Henry Ford Hospital Detroit Mich

[**] Audiologist Section of Audiology Division of Otolaryngology Henry Ford Hospital Detroit Mich

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speech audiometer, in a two-room testing unit, using monitored live voice techniques

Thresholds for bone and air conduction throughout have been stated in terms of the equivalent S R T as determined by the Fletcher formula The Fletcher formula is the average of the two best threshold responses for 500, 1000 and 2000 c p s

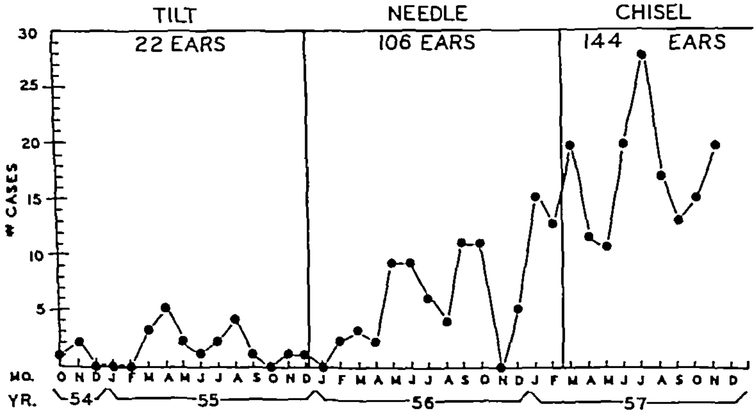

Fig 1 Chart showing the operative method number and date of 269 stapes mobilization operations

CLASSIFICATION OF RESULTS

1 Successful

a 30 db or better pure tone threshold

b 20 db or smaller bone-air gap

2 Improved

10 db or more improvement of pure tone threshold but not successful

3 Unchanged

Less than 10 db change of pure tone threshold

4 Hearing Loss

10 db or more loss of pure tone threshold

their air conduction thresholds to practical hearing levels because of sensory-neural deafness and who experience a successful mobilization were usually greatly pleased with the comfort afforded by the lower amplification requirements. The ear with the poorest hearing was always operated first, and only if the hearing improved beyond the opposite ear was the opposite ear operated. Patients with unilateral otosclerosis were subjected to surgery only if they felt that their hearing loss was an occupational or social handicap (seven of 269 ears).

The operations all were performed with local anesthesia by the trans-tympanic route. The head light and 2.5 power loupe were used for some early cases, but nearly all were done with the aid of a Zeiss operating microscope. For the past year, this instrument has been used for the entire operation.

The patients were discharged from the hospital the day following surgery unless they complained of vertigo. Tetracycline, 250 mgms. every six hours, was given for five days post-operatively.

CRITERIA OF SUCCESS AND FAILURE

We have not rated our patients into classes of predicted success, as is done for patients being considered for fenestration surgery, because for stapes mobilization we are not restricted by the bone conduction levels. From October 25, 1954, to December 1, 1957, two hundred and sixty-nine mobilizations were performed, most of these being performed in the past year. We have determined the success rate for each of the three groups of patients in which the tilt (22 ears), needle (106 ears) and chisel (144 ears) techniques were used (see Fig. 1).

We (A.B.G. and M.R.C.) administered all pure tone tests in acoustically-treated rooms with an ambient noise level of less than 50 db. in the critical frequency bands with commercially available clinical audiometers. The calibration of each audiometer was standardized regularly with the Allison calibration unit, Model 3A. Speech tests were administered either with the above equipment or, using the regularly calibrated

The results were far more gratifying than those accomplished with the tilt technique, but at the end of six months, 20 per cent of the early successes had again lost their gain.

CHISEL METHOD

Whereas the mild and moderate ankylosis could be mobilized quite satisfactorily with needles, the method was not often successful in mobilization of the more severely ankylosed footplate. The next logical step was the use of chisels to cut through the otosclerotic foci. For the development of the technique and the design of the instruments, we are indebted to Heermann. I may not use the instruments in precisely the manner that he does, but this is not important as long as the end result is lysis of the stapedial footplate in continuity with one or both crura. Heermann first designed a slightly curved and a straight chisel* which I now refer to as the "heavy" models and which I use first on all but the very thin otosclerotic foci. About six months ago he designed lighter models which I use continuously, and refer to as the curved, reversed-curved, and straight "light" models. In order that the reader may gain a clear impression of the shape and size of the chisels in relation to the stapes, they are shown to scale in Fig. 2.

TABLE II

Needle Method—106 Ears

Early Results (1 month)			
Successes	Threshold	60	62%
	Bone-Air Gap	6	
Improved		11	10%
No Change		27	26%
Loss		2	2%
No Early Record		1	1%
Late Results (Average 6 months)			
Successes	Threshold	44	47%
	Bone-Air Gap	6	
Improved		10	9%
No Change		33	31%
Loss		4	4%
No Late Record		9	9%

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*Available from F. L. Fischer Co., Freiburg im Breisgau, Germany.

The three groups were rated in terms of early and late successes, the early successes being determined by audiometric tests taken about one month after operation, and the late successes three months or longer after operation, thus, the average time after operation for the late tests was eighteen months for the "tilt" ears, six months for the "needle" ears, and four months for the "chisel" ears

TILT TECHNIQUE

After I first saw Rosen demonstrate his method in October, 1954, I attempted to follow it As much as I dislike introducing new terminology, I cannot bring myself to describe my own attempts to mobilize by applying pressure to the neck of the stapes as the "Rosen method", for to do so would be no compliment to Rosen Obviously he had developed a degree of skill in applying this force which eluded me, for my attempts to rock or tilt the stapes very often resulted in crural fractures The results are shown in Table I

TABLE I

Tilt Method—22 Ears

Success		
Early (1 month)	4	(18%)
Late (average 18 months)	3	(14%)
Improved	6	
No Change	12	
Loss	1	

NEEDLE TECHNIQUE

I was very grateful when House and Goodhill showed me their techniques in January, 1956, which consisted of the skillful application of force to the head of the stapes by a needle and, if that failed, by prying, pushing and cutting the margins of the footplate with sharp needles, great care being directed at mobilizing the footplate without breaking the crura During 1956 and early 1957 I utilized the needles to the best of my ability on one hundred and six ears Results are shown in Table II sary, to acquire the best possible view of the crura and footplate I make no attempt to mobilize the stapes with trans-incudal or trans-capitulum force, but proceed immediately to make the first chisel placement anterior and adjacent to the anterior crus so as to cut through the anterior otosclerotic focus

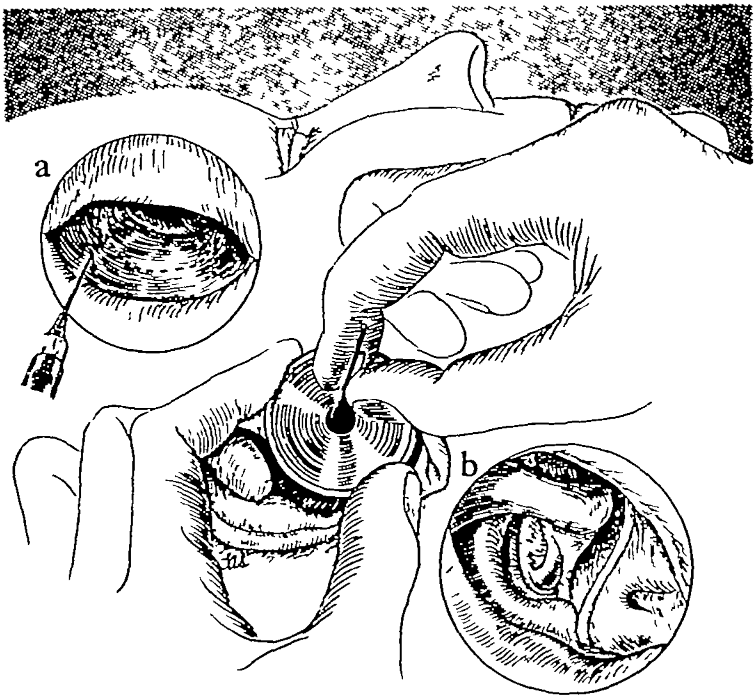

Fig 3 a. Sites of injection for anesthetic agent (3 dots) and location of meatal incisions (broken line) b Typical view of operative field Center Method of placing chisel utilizing 10 to 16 power magnification

A handle can be purchased to hold the chisels, but I prefer to hold the chisel in position by grasping the small tab located on the shaft with the bare fingers of either the left or the right hand, whichever is the most convenient, while the oppositie hand holds the speculum The nurse or assistant taps the chisel with a small hammer, using light to heavier blows, as directed by the operator Sometimes the nurse holds the speculum, leaving the operator's opposite hand to

The injection sites, skin incisions, position of the hands when holding the chisel and the normal view of the operative field are seen in Fig 3 The skin flap must be large enough to cover the defect left by removing bony annulus posteriorly and to allow inspection of the round window Bony annulus can be removed with either curettes or burs Accumulation of bone dust makes the bur somewhat objectionable Sometimes electrocautery is needed to control bleeding from the skin incisions The chorda-tympani nerve usually is reflected downward, but occasionally upward, so as to preserve it The stapes is touched gently with a needle to determine whether it is fixed In only one ear (of 269) was a mobile stapes found, and this ear was one of three with total round window closure, the others having stapes ankylosis in addition Curtains and bridges of mucous membrane are cut away, if neces-

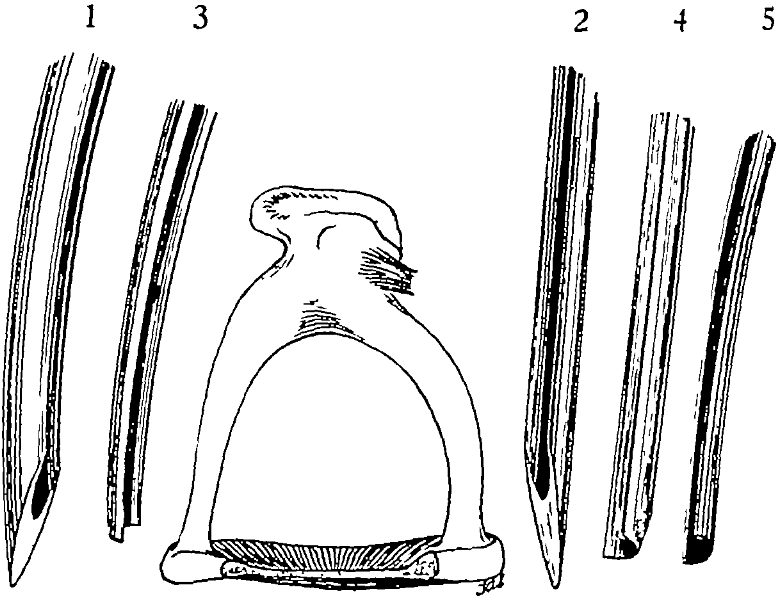

Fig 2 Drawing of normal stapes with part of footplate margin cut away to show thin central region and views of the chisel points drawn to scale and enlarged For the anterior margin of the footplate Chisel 1 (heavy curved) and Chisel 3 (light curved) are usually best suited although No 2 (heavy straight) and No 4 (light straight) may be better in some cases Nos 2 and 4 are used for the superior margin and No 5 (reverse curved) for the posterior margin

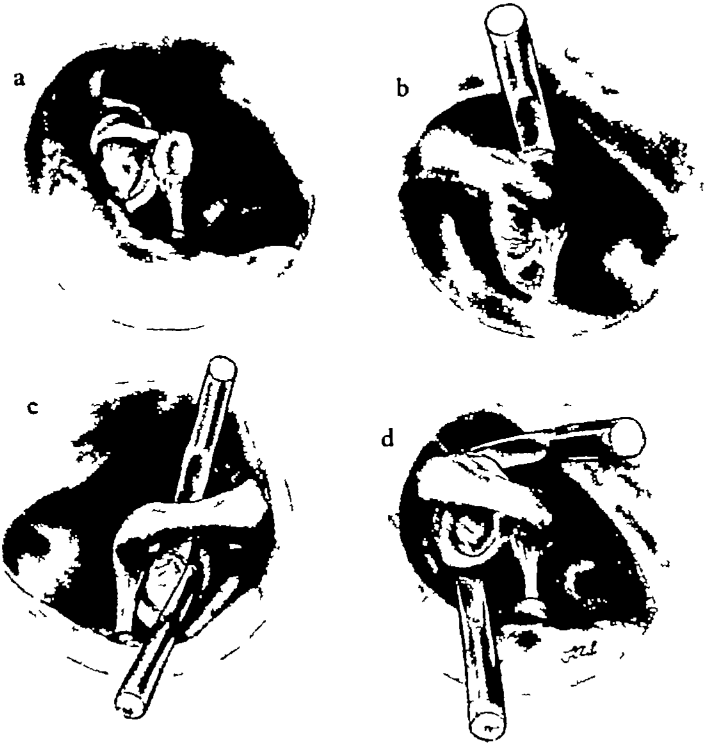

Fig 5 a. Incus removed in cadaver specimen to show anatomy of footplate region b Chisel placed at anterior margin of footplate c. Chisels placed anteriorly and superiorly d Chisels placed anteriorly and posteriorly

wield the hammer The curved chisel is best suited to the anterior margin of the footplate, although the straight ones can be used in some cases, the "heavy" model being used first until a slight movement of the stapes is seen, after which the "light" model may be used to cut the remainder of the focus With two or three light taps of the chisel, thin otosclerotic foci will be cut, and total mobilization of the stapes will be accomplished For thick and extensive otosclerotic foci the "heavy" model chisel may be used in two or three anterior locations, so as to circumferentially cut the focus Then the straight "heavy" or the straight "light"

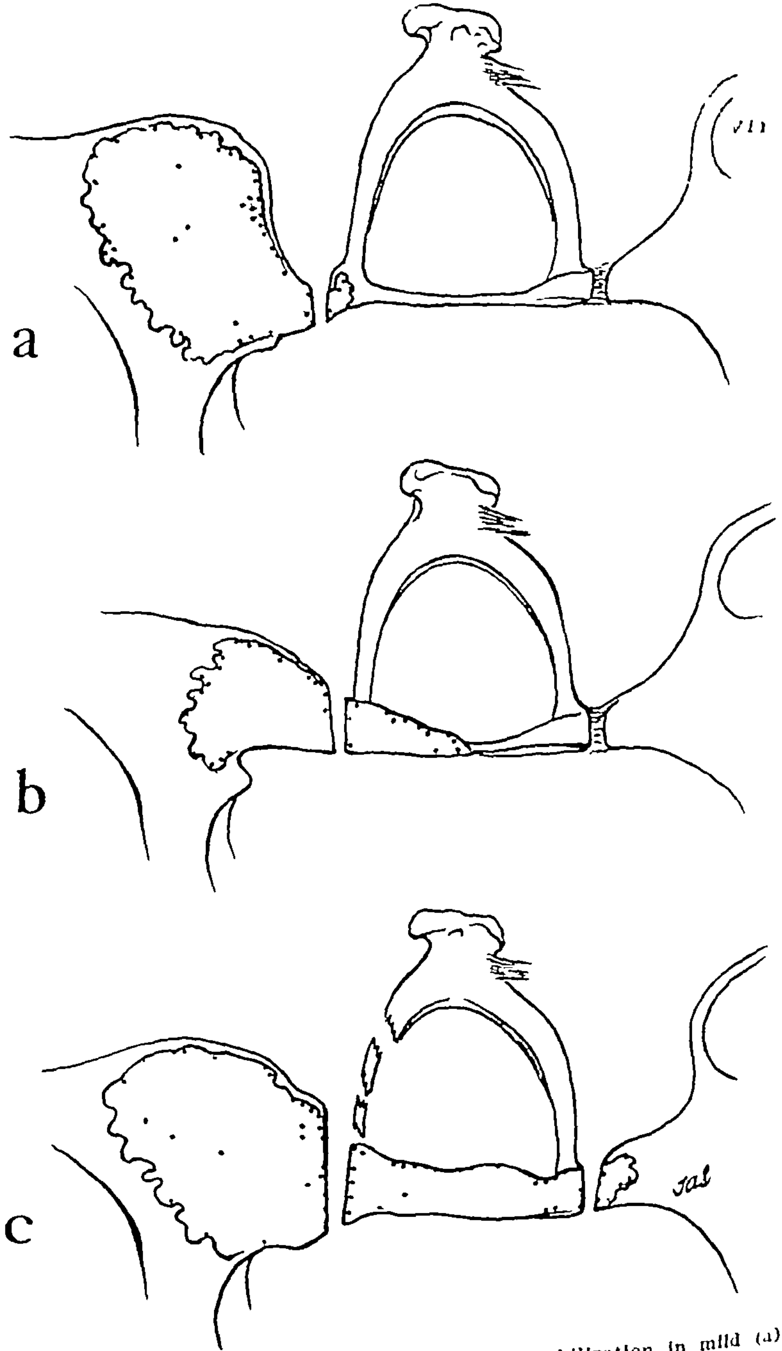

Fig 4 Objectives to be achieved in stapes mobilization in mild (a) moderate (b) and severe (c) otosclerotic lesions

nella effect The objective of mobilization in mild, moderate and severely ankylosed stapes is seen in the diagrammatic sketches in Fig 4

After the footplate is loose, a needle is inserted into the incudo-stapedial joint and rocking movements, as well as in-and-out movements, are made to insure complete mobilization of the stapes, using care not to dislocate the incudo-stapedial joint A disarticulated, or subluxated, joint should be avoided, for this might result in some hearing loss, and a few db one way or another can be critical for the patient

TABLE III

Chisel Method

Early Results (1 month)	144 ears		
Successes			
Thresholds	99	69%	
Bone-Air Gap	10	7%	76%
Improved	20		14%
No Change	12		8%
Loss	3		2%
Late Results (average 4 months)	74 ears		
Successes			
Thresholds	49	66%	
Bone-Air Gap	4	6%	72%
Improved	9		12%
No Change	10		13%
Loss	2		3%

Surgical audiometry, that is, hearing testing in the operating room, is employed in all operations using the Ambco Otometer In general, hearing improvement in the operating room indicated a successful mobilization, but many ears which did not improve in the operating room also had a subsequent good result We continue to use surgical audiometry but do not consider it essential for successful surgery A much more reliable indicator is the surgeon's visual and tactile impression of the state of mobility of the stapedial footplate

The most common chisel placements are shown in Fig 5 Some common otosclerotic lesions are seen in Fig 6 and were sketched by Mr Stebbins at the time of operation The

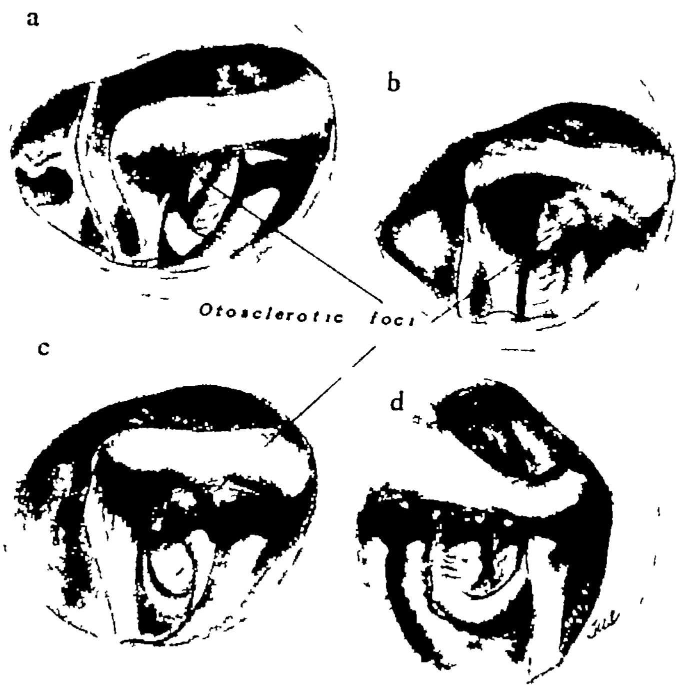

Fig 6 a b and c show moderate otosclerotic lesions as seen at operation d shows a dense otosclerotic lesion involving the entire footplate Chisel marks can be seen along both superior and inferior margin It was impossible to accomplish mobilization in this ear There were five such cases in the total of 269

model chisel is used superiorly, and the reverse curved chisel is used posteriorly to accomplish further lysis as necessary

Occasionally there are linear fractures through the footplate when the operation is completed, but this is not serious so long as one or both crura remain intact and in continuity with part of the footplate

In ears with very thick, extensive otosclerotic foci, it is not possible to preserve the continuity of the anterior crus, but in these cases a thorough lysis of part of the footplate must be accomplished with the posterior crus providing the colum-

It is interesting to note that nine ears were re-operated and of these success was attained in six The high success rate of re-operated ears probably is because the chisel method was used in the second operation The results are summarized as follows

METHOD

Original Operation		Re-Operation	
Tilt	3	Needle	1
Chisel	6	Chisel	8
	9		9

RE-OPERATION RESULTS

	Unchanged	Success
Needle	1	0
Chisel	2	6
	3	6

SUMMARY

The stapes mobilization operation was performed on 269 patients between October, 1954, and December, 1957 The late success rate (three months, plus) utilizing the tilt technique was 14 per cent of 22 ears, with the needle technique it was 47 per cent of 106 ears, and, with the chisel technique it was 72 per cent of 72 ears

The chisels designed by Heermann are effective instruments for mobilizing the footplate while preserving the continuity of one or both crura and maintaining thereby the columnella effect

Acknowledgments We express our appreciation to Mr Thomas Stebbins for his illustrations, and thank Mr David Shephard, Mr Dennis Bagaria and Mrs Harold F Schuknecht for their assistance in analyzing the audiometric data

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results of the chisel method are shown in Table III The chief reason why we have late results only on 74 of the 144 ears, is that 43 operations were performed less than three months before the analysis was made, and 12 patients lived out-of-town and were inaccessible An interesting difference between the chisel group and the needle group is that the percentage of late successes (three months or longer) is almost as high as the early successes (one month) The number of patients who lost their early hearing gain was somewhat less, but the main difference was that a number of patients passed from the improved to the success group after one month

COMMENTS

The complications for this entire group of 269 operations are summarized as follows

Tears of the tympanic membrane	25
Persisting perforations	0
Profound hearing losses	2
One sterile labyrinthitis, one cause unknown	
Otitis media (after five days)	3
Otitis externa	4
Postural vertigo	2

Hearing losses were experienced in eight (3 per cent of 269 ears The cases are listed as follows

Tilt (1 of 22)

12 5 db , cause unknown

Needle (4 of 106)

15 db , pneumatic hammer

15 db , stapes depressed into oval window

15 db , cause unknown

Profound loss—initial success—loss after laparotomy

Chisel (3 of 144)

10 db , cause unknown

Profound loss, sterile labyrinthitis

10 db , footplate fenestration with removal of incus

A GUIDE FOR STAPES SURGERY BASED ON A NEW SURGICAL CLASSIFICATION OF OTOSCLEROSIS*

Richard J. Bellucci, M.D.,

New York, N. Y.

A better appreciation of the gross pathology of otosclerosis involving the oval window and stapes had been obtained with the introduction to otology of the surgical microscope. Although the binocular loupes and headlamp were considered satisfactory at one time, it seldom was possible with this equipment to obtain a precise concept of the otosclerotic involvement or to appreciate the results of the mobilization procedure. In retrospect, the mobilization operation as introduced by Rosen[1] can be considered a gross procedure which does not account for the variations in type and distribution of the otosclerotic lesion. In the original description of the operation, a clear view of incudo-stapedial joint and stapedius muscle tendon was considered sufficient visualization, and the procedure simply required the application of the force to the neck of the stapes in the direction of the stapedius muscle tendon. No investigation of the footplate was considered necessary, and poor visualization had to be supplemented by a keenly developed tactile sense. This type of surgery produced successful results in comparatively few patients—presumably those with early and small otosclerotic lesions. In the more advanced cases, both crura were often fractured before the stapes footplate could be mobilized. The application of force either to the head and neck of the stapes or by the trans-incudal technique[2,3] without adequate visualization of the otosclerotic lesion at the footplate did not permit an opportunity to modify the technique according to location and degree of pathology; consequently, only cases of minimal otosclerotic involvement could be mobilized, accounting for

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*Read before the meeting of the Eastern Section American Laryngological Rhinological and Otological Society Philadelphia, January 9-10 1958.

Editor's Note: This manuscript received in The Laryngoscope Office and accepted for publication Dec. 28 1957.

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PROGRAM OF THE SEVENTH INTERNATIONAL CONGRESS OF BRONCHOESOPHAGOLOGY

Meeting Place—Kyoto University, Kyoto, Japan

Friday, September 12th, 1958

8 00 P M-10 00 P M—Reception (Party) Shimomura House in Kyoto

Saturday, September 13th

8 00 A M—Inaugural Session (in Kyoto University Hall)

9 00 A M-12 00 M—First Scientific Session

12 00 M-2 00 P M—Luncheon (Reception The Place not decided)

2 00 P M-6 00 P M—Sightseeing in Kyoto

8 00 P M—Banquet, Miyako Hotel

Sunday, September 14th

8 00 A M-11 30 A M—Second Scientific Session

11 30 A M-12 00 M—Closing Ceremony

12 00 M—Departure for sightseeing in Nara

1 00 P M—Luncheon, Nara Hotel

2 00 P M-6 00 P M—Sightseeing in Nara

7 00 P M—Return to Kyoto

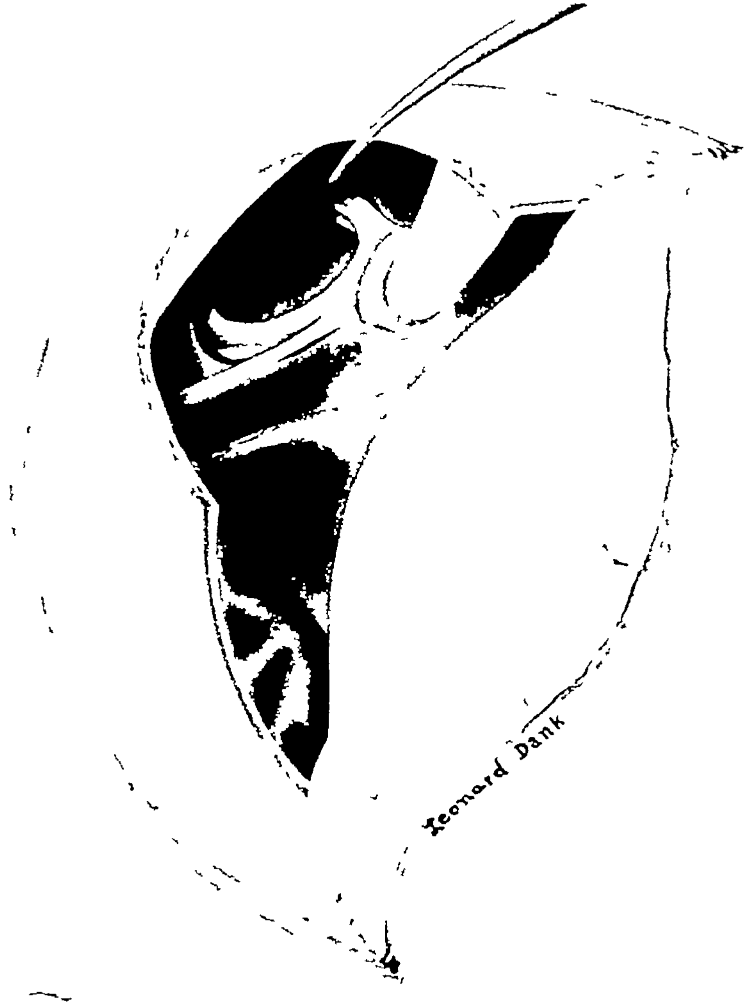

Fig 1 Class I—Early Otosclerosis Stapedio-vestibular joint space is not reduced and otosclerosis is not visible The footplate appears thin and bluish in color

structures are situated so far posteriorly with respect to the external auditory canal that the incus is not visible when the drum is reflected In these cases the bone of the posterior canal wall must be removed widely over the incus at the annulus The removal of bone in this area is a relatively the low percentage of good results obtained by these techniques

It is generally accepted that the best results are obtained when the crura of the stapes are not damaged during the mobilization procedure It is through the intact ossicular chain that sound pressure normally is transmitted to the oval window, and every effort should be made to preserve this natural route of conduction It is not rational, therefore, to fracture the crura and then attempt to mobilize the footplate of the stapes The technique of mobilization in which the forces are applied either to the head and neck of the stapes or by trans-incudinal means have now been discarded All mobilizing forces are applied directly to the point of fixation at the footplate which considerably diminishes the risk of fracturing the crura before the footplate of the stapes can be mobilized

The application of the mobilizing forces directly to the footplate had not been safe when no more magnification was available other than the loupes and headlamp With high magnification the footplate of the stapes can be manipulated under the combined sensations of touch and binocular vision making possible positive control over the mobilizing force Surgical penetration through the footplate into the vestibule during the mobilization operation rarely occurs when the stapes is visualized under high magnification, and consequently vertigo is experienced in very few cases

High magnification also permits the careful examination of the position, extent and character of the otosclerotic lesion[4] It is then possible to modify the mobilization technique according to the pathology encountered As an excellent exposure of the footplate is obtained in over 90 per cent of the cases, there are few occasions when the surgeon does not have the operation under his complete visual control With the use of the microscope, the pathology can be seen clearly, and a carefully planned course of mobilization procedure can be chosen In less than 10 per cent of the cases the field is obscured by the tortuosity and size of the external auditory canal or by the anatomical variations in the position of the oval window in the middle ear At times the middle ear

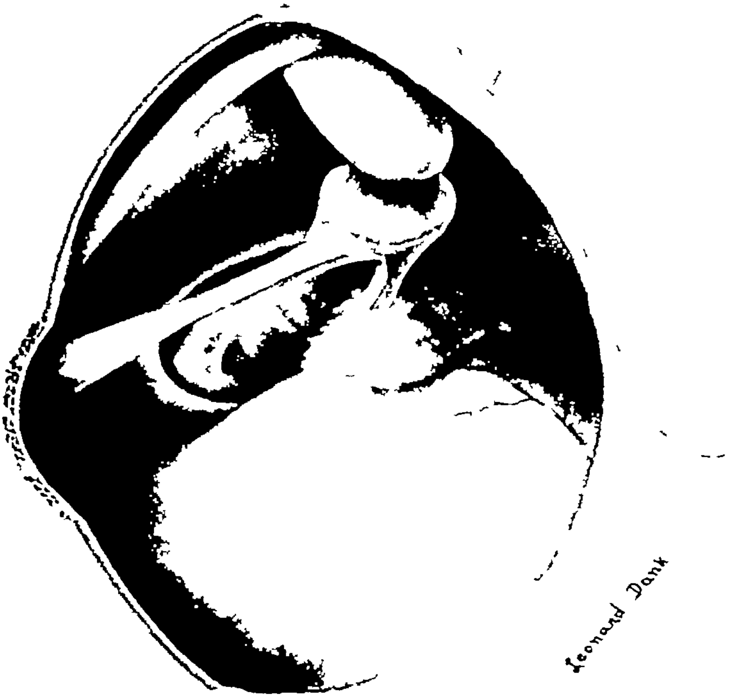

Fig 3 Class III—Advanced Otosclerosis Large otosclerotic lesion which obliterates the stapedio-vestibular joint space and involves one crus of stapes The other crus and most of the footplate are free of otosclerosis

angulation and depth of the stapes in the oval window niche can be so unfavorable that it can impose a considerable handicap to the surgeon Routinely, the mobilizing forces are applied only to those portions of the stapes footplate which are clearly seen In these unfavorable cases visualization is

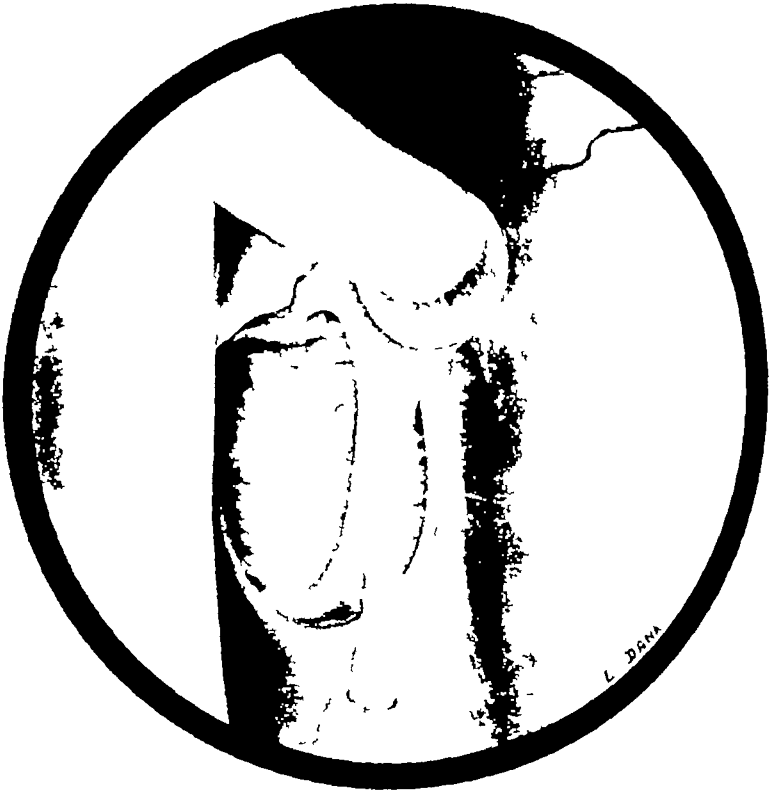

Fig 2 Class II—Moderately Advanced Otosclerosis Stapedio-vestibular joint space is bridged by an otosclerotic lesion which has advanced from the vestibular wall to the adjacent portion of the footplate The joint space is visibly narrowed but the crura of the stapes are not involved in the lesion

safe procedure and should not compromise adequate visualization of the stapedial footplate

Anatomical variations within normal limits often occur in the region of the oval window and the stapes The crura of the stapes vary in size considerably Some are extremely fragile and are injured easily The crura also may assume a variety of positions with regard to the surrounding structures Quite unfavorable for surgery is the deeply seated footplate in an oval window area which has a high lip at the promontory side or a facial nerve which overhangs the oval window impairing direct visualization (see Fig 6) The

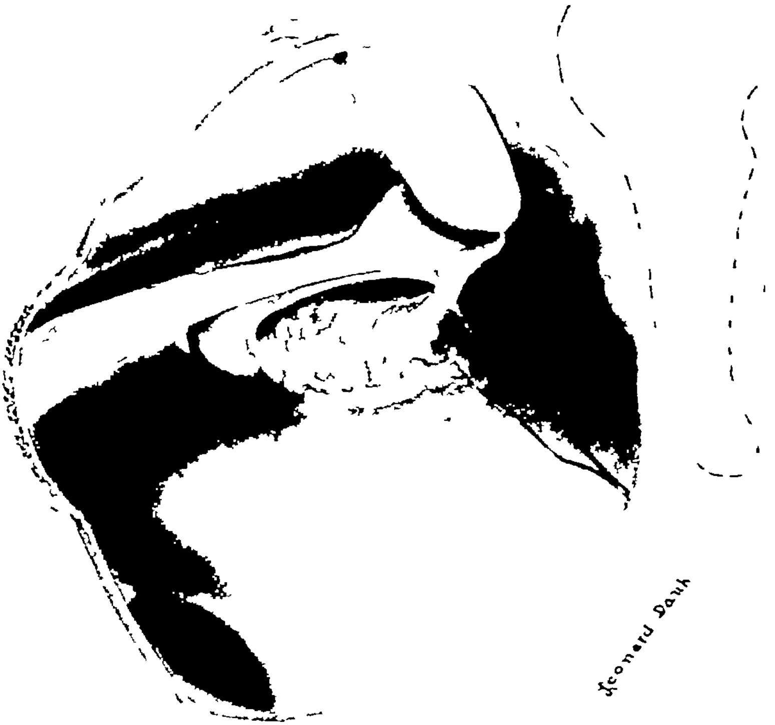

Fig 5 Class IV—Unfavorable for Mobilization Entire footplate of stapes has been replaced by otosclerosis

fixation at the stapedio-vestibular joint As the footplate normally has a slight degree of flexibility, it is possible, using light pressure of the needle, to observe slight motion of one mobile end of the footplate of the stapes when the other is fixed solidly by otosclerosis The small amount of motion obtained when the stapes is bent can be appreciated only with binocular vision under high magnification This information will direct the application of the mobilizing forces

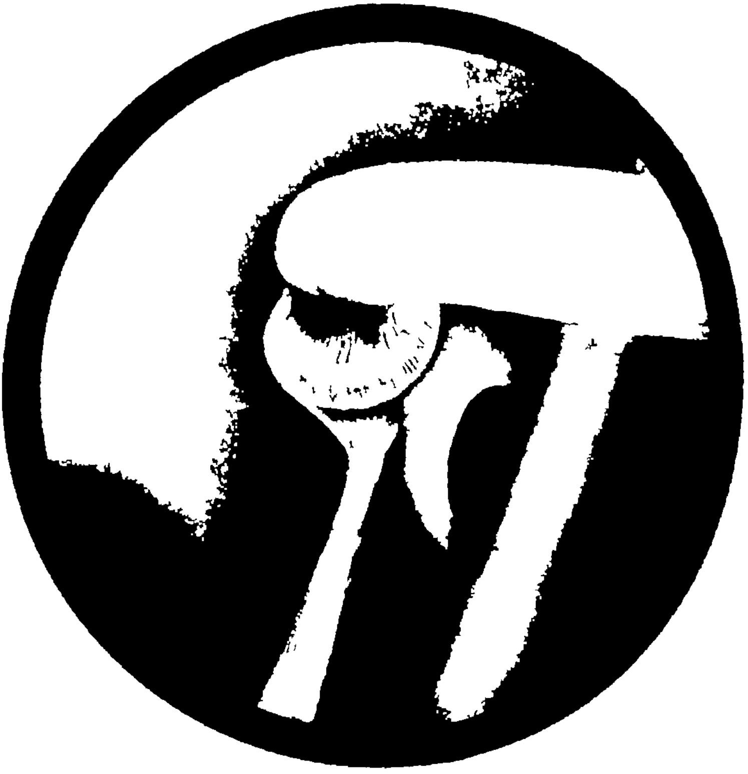

Fig 4 Class IV—Unfavorable for Mobilization Reduction of oval window niche to a narrow slit preventing adequate visualization and controlled instrumentation The facial nerve overhangs the footplate and the stapes is crowded by a large otoscerotic lesion which projects from the promontory

poor, and blind application of the mobilizing instruments on the footplate is not recommended

PALPATION

Although adequate exposure and direct visualization of the oval window niche are important, much can be gained by careful palpation It is possible to locate the region of fixation by applying gentle pressure with a needle in orderly sequence to the incus, incudo-stapedial joint, and head and crura of the stapes Further palpation of the footplate directly will reveal information regarding the exact point of tion is considered essential in evaluating any particular case for revision

Following a successful mobilization it is possible to check the ossicular chain for continuity by observing the motion of the footplate when downward pressure is applied at the lenticular process of the incus When the ossicular continuity has been preserved, motion induced in the footplate can be seen directly and is transmitted also to the round window niche where it can be visible This provides conclusive proof that sound pressure is passing through the cochlea Less emphasis, therefore, can be placed on subjective responses and audiometry in the operating room

SURGICAL CLASSIFICATION OF OTOSCLEROSIS

Adequate information for classification has been obtained when the exact location, nature and position of the otosclerotic lesion has been determined The selection now can be made of a mobilization technique which will be the most suitable to manage the particular type of lesion encountered When sufficient surgical experience has been obtained in recognizing the variations in the distribution and degree of involvement assumed by otosclerosis, it can be understood easily why one mobilization technique can not give a satisfactory percentage of good results In this study a higher percentage of good results has been obtained only when the technique of mobilization had been modified to meet the particular variations of the otosclerotic lesion The operation for the mobilization of the stapes at this point takes on a new character The presenting anatomy and pathology must be studied carefully and a surgical plan is formed either to circumvent the lesion when it is extensive, or to apply the mobilizing forces directly to the point of fixation causing separation through the otosclerotic lesion

Although innumerable variations occur in middle ear anatomy and in the otosclerotic involvement, certain similarities have become evident which permit a classification on anatomic and pathologic basis All cases can be catalogued within four general classes, and a surgical technique is described which is suitable to deal with each type of involvement

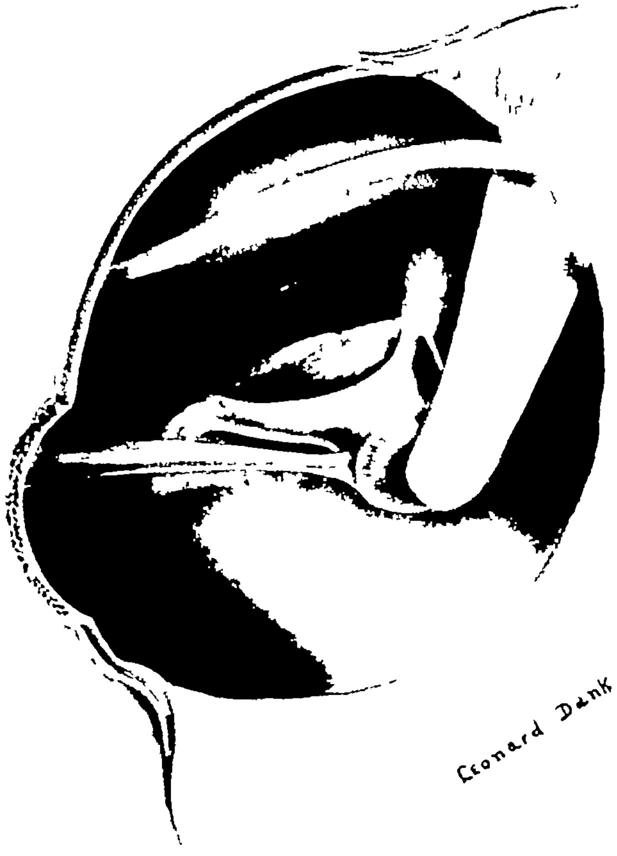

Fig 6 Class IV—Unfavorable for Mobilization Both crura are fixed by the otosclerotic lesion at the lip of the promontory The footplate of the stapes rests in a very deep oval window niche and is obscured by a prominent facial nerve

to the area involved by the otosclerotic lesion Injury to other parts of the stapes not responsible for the ankylosis can be avoided by these means

The results of the mobilization procedure also can be determined accurately by palpation Injured portions of the stapes can be easily recognized and should be noted This informa-

2 Definite narrowing of stapedio-vestibular joint by visible otosclerosis is present The lesion usually involves a portion of the footplate of the stapes but neither crus is involved in the otosclerotic lesion

3 The usual normal blue color of the footplate has remained unchanged except for a region near the otosclerotic focus, where it is white and opaque

4 Palpation under magnification reveals solid fixation at one end of the stapes The other end exhibits slight motion

In this study, most cases of otosclerosis presented the characteristics of Class II Methods of mobilization which depend upon the strength of the crura are successful only occasionally when the otosclerotic lesion has advanced to this degree Under these conditions the crura usually are not strong enough to withstand the pressure required to free the footplate, and fractures of the crura occur often when the mobilizing force is applied to the head or neck of the stapes Application of the mobilizing force directly to the otosclerotic lesion at the footplate permits mobilization in many of these cases without the danger of losing ossicular continuity The application of pressure, depressing the footplate into the oval window, with a sharp curved needle at the base of the involved crus nearest the fixation can be an alternate means of applying the mobilizing force When this involvement is extensive, extreme care is needed to prevent penetration into the vestibule or injury to crura When attempting to achieve mobility, the otosclerotic lesion can be weakened by many re-applications of superficial needle punctures performed under direct visualization These punctures can be done safely under the control of vision and touch During this type of mobilization there is usually a fracture of the footplate or separation of the stapedio-vestibular joint with a loss of a small amount of perilymphatic fluid As the pressure has been applied only to the footplate, the crura usually remain intact Occasionally the crus nearest the otosclerotic lesion may be injured This is not of serious consequence as hearing improvement is possible when continuity is maintained between the intact crus and a mobile portion of the footplate

Class I, early otosclerosis has been observed in 36 per cent of cases studied (see Fig 1)

Characteristics

1 Good exposure and visualization of footplate is possible

2 No evidence of narrowing of stapedio-vestibular joint and no otosclerosis is visible

3 The footplate of stapes is of a normal blue color, smooth and regular

4 Palpation under magnification reveals fixation at one end of the footplate of the stapes, slight motion can be obtained at the other end

Cases with early otosclerosis, in which the lesion is very small and not visible with the microscope, are grouped in this class The otosclerotic lesion is assumed to be either entirely fibrous or containing a minimal amount of calcification Usually mobilization is accomplished easily by gentle pressure of the needle at the point of footplate fixation Needle pressure (forcing the footplate into the oval window) at the base of the crus near the stapedio-vestibular joint usually is successful when attempting to achieve footplate mobility (see Fig 1) Penetration into the joint space is rare, as the mobilizing force is under the direct control of vision and touch, and escape of perilymph also is rarely seen It is reasonable to assume that most cases which terminate successfully when the mobilizing force was applied to the neck or head of the stapes had minimal otosclerotic involvement and could be included in Class I Those cases with more advanced lesions, such as those grouped in Classes II and III would have terminated unfavorably with the early techniques, as these lesions needed more force for footplate mobilization than could be applied through the crura of the stapes

Class II moderately advanced otosclerosis was observed in 11 per cent of cases (see Fig 2)

Characteristics

1 Good exposure and visualization of footplate is obtained to obtain a significant improvement in hearing, therefore, all efforts should be made to prevent fragmentation A crus of the stapes resting in the perilymph of the oval window without an attached portion of footplate does not perform well, and a satisfactory improvement in hearing is usually not obtained

Class IV, unfavorable for mobilization of the stapes, are cases with very advanced otosclerosis and those complicated by extremely difficult anatomic variations Only nine per cent of cases in this study were found to have these characteristics

Characteristics

1 There is poor exposure and visualization of oval window due to extreme anatomic variations (see Fig 4)

2 Large otosclerotic lesions may be seen, which have replaced the footplate completely with solid white bone obliterating the stapedio-vestibular joint (see Fig 5)

3 Extensive otosclerotic lesions originating from the margin at the promontory and involving both crura are also unfavorable Included are cases with apparently normal blue footplate, but the crura of the stapes are fixed solidly at the promontory edge (see Fig 6) In these cases the footplate of the stapes lies deep in the oval window niche The stapes is tilted toward the promontory lip and otosclerosis involves both crura just below the neck

Cases with unfavorable prognosis regarding the application of mobilization procedures are grouped in Class IV These cases are considered unfavorable when the anatomy of the middle ear is abnormal, permitting neither adequate visualization nor controlled instrumentation at the footplate, the prognosis is also unfavorable when both crura are fixed by otosclerosis In these cases the footplate rests deep in the niche of the oval window, and fixation of the crura occurs usually at the lip of the promontory The footplate itself may be normal in appearance, but continuity of the ossicular chain is usually interrupted in attempting to release the fixed crura from the promontory

The technique of applying the mobilizing force directly to otosclerotic lesion at the footplate has been most successful in Class II Many of these cases would have terminated unsuccessfully with fractures of the crura if the mobilizing forces had been applied to head or neck of the stapes Application of force to the otosclerotic lesion meets the resistance at the strongest point, providing greater opportunity for successful mobilization of the stapes The difference in statistics published in 1956[7] and those reported in this study represent chiefly the accomplishments of this present technique in this class of otosclerotic involvement

Class III, advanced otosclerosis, was found in 14 per cent of cases studied

Characteristics

1 Good exposure and visualization of footplate is present

2 A large otosclerotic lesion involves the stapedio-vestibular joint, one crus of the stapes, and a portion of the footplate (see Fig 3)

3 Near the otosclerotic lesion, the normal blue color of the footplate is replaced by solid white opaque bone

4 Palpation reveals solid fixation of the greater part of the footplate, but slight motion can be demonstrated at the uninvolved end of the footplate

When a large otosclerotic lesion of this type is found no attempt is made to fracture directly through the lesion The crus is divided above the otosclerotic mass as recommended by Fowler,[5] permitting the uninvolved crus to maintain continuity with the uninvolved portion of the footplate The footplate is fractured in its midportion by multiple superficial punctures with a fine curved needle Usually there is an escape of perilymph through the fractured footplate Occasionally other lines of fracture occur with fragmentation of the footplate into several parts This is to be avoided as only a small fragment of the footplate may remain attached to the mobile crus, insufficient to permit transmission of sound pressures Approximately one-half of the footplate attached to the functioning crus has been found necessary

It is unfortunate that this decision excludes cases with weak cochlear function, as some of the most impressive results obtained by mobilization of the stapes procedures are in this group Although a remarkable improvement in hearing has been obtained following the mobilization of stapes in many patients with weak cochlear function, these cases are not represented in this statistical analysis By accepting only ideal candidates it is possible to compare accurately results obtained by the techniques presently in use with the former procedures in which the mobilizing force was applied to the neck of the stapes Considerable improvement has been found to exist when the latter group of cases is compared to the former

When the mobilizing force was applied directly to the otosclerotic lesion at the footplate, an immediate improvement (one week postoperative) in hearing to above the 30 db level was obtained in 72 per cent of cases This figure is more than double that obtained (35 per cent) when the force was applied to the neck or head of the stapes This difference in percentage occurred as the result of a reduced number of injuries to the crura of the stapes and to the preservation of the continuity of the entire ossicular chain The earlier techniques depended chiefly on the strength of the crura for mobilization of the footplate, and in most cases once the crura were fractured no further manipulation was possible The application of force directly to the point of fixation permits considerably more maneuvering and manipulation, yet preserving ossicular continuity Although the figure of 72 per cent is encouraging, failure to obtain immediate improvement in hearing occurred in 28 per cent In these cases the otosclerotic lesion was either too extensive to be safely mobilized, the anatomy of the oval window was unfavorable, or, accidental fracture of both crura occurred with loss of ossicular continuity Unfavorable anatomy and pathology accounted for nine per cent of these failures, and 17 per cent did not have a satisfactory improvement in hearing because of accidental injury to the footplate or crura of the stapes In two per cent of these cases the otosclerotic lesion also involved the round window niche

The prognosis also is considered unfavorable when the otosclerotic lesion has entirely replaced the footplate, obliterating the stapedio-vestibular joint In this study the crura were found freely movable in two cases In both a large otosclerotic mass had replaced the footplate completely and had reduced the crura to thin fibrous and flexible strands of tissue Chisels, burs and hooks used to achieve mobility or fenestration of the footplate, when completely replaced by otosclerosis, were found to expose the labyrinth to undue risks When confronted by anatomic and pathologic conditions characteristic of Class IV, mobilization of the stapes operation is not recommended, as the safety of a controlled operation is lost It is preferable to consider the fenestration of the horizontal canal, which avoids this area of excessive otosclerotic involvement and provides the technical control required for this delicate surgery House[6] agrees with this point of view Deliberate fenestration of the footplate has not been attempted as all cases in which the footplate has been fenestrated accidentally have had only a slight initial improvement in hearing which was lost within a relatively short time It is well recognized that one type of medical or surgical management cannot be ideal for all variations of a disease process This medical axiom should be applied to the stapes mobilization operation

DISCUSSION OF RESULTS

The results obtained in a series of 100 cases, considered ideal for fenestration surgery were reported in 1956 At that time it was believed valuable to establish a baseline for the new mobilization of stapes operation performed exactly as introduced by Rosen, using candidates ideal for the fenestration operation (horizontal semi-circular canal) Attempts to represent statistically all cases acceptable for mobilization surgery, including those with weak cochlea function, yet possessing some degree of cochlea reserve, produced considerable confusion in the presentation of results, therefore, only results obtained with ideal candidates were reported in 1956 Again, in this present study of 100 cases, using the described surgical techniques, only ideal cases which satisfied the criteria for fenestration operation have been included the footplate had been achieved often by a fracture directly through a solid but active otosclerotic lesion which rarely would have occurred by the earlier techniques The footplate techniques also create more reaction at the site of the ankylosis, possibly hastening re-fixation in some cases

Vertigo frequently has been encountered during the operation for the mobilization of the stapes This symptom can be induced by merely applying the aspiration tube near the round window niche, or can be caused in the process of mobilizing the stapes

When the mobilizing force was applied to the head or neck of stapes fewer patients complained of vertigo at the time of surgery, and only 2 0 per cent experienced vertigo lasting over 24 hours Table II presents a comparison with later cases, in which the mobilizing force was applied directly to the footplate of the stapes Although many more patients experienced vertigo at the time of surgery, few patients continued to experience vertigo after 24 hours

TABLE II

Duration of Vertigo	Mobilization at Head or Neck	Direct Mobilization at Footplate
At Operation	10 0%	31%
Less than 24 hrs	3 2%	10%
More than 24 hrs	2 0%	6%

These results are rather impressive, as they testify that the labyrinth is a hearty structure able to withstand surgical trauma Vertigo as a result of shallow penetrations into the vestibule, accompanied by the loss of perilymph through a fracture in the footplate, has been observed to last several hours after surgery Deeper penetration which may disturb the saccule or the utricle causes disturbances in equilibrium which usually terminate within a week It also has been noted that a period of vertigo may follow an injury to the vestibular sense organs without causing a loss of hearing below the preoperative level It has been found preferable to cover perforations of the footplate with a small piece of

It is significant to note from Table I that the application of the mobilizing force to the head or neck of the stapes produced an immediate improvement in 35 per cent of the cases Only six per cent of these improved cases returned to the former level of hearing within a period of four months In contrast to these figures are the results obtained with the present techniques Although it was possible to obtain an immediate improvement in hearing in 72 per cent of the cases, 17 per cent returned to the preoperative level of hearing within four months A reasonable explanation for this difference can be suggested as the cases which obtained a satisfactory improvement in hearing with the early techniques were those possessing small and possible fibrous lesions of otosclerosis With this early procedure, little trauma to the stapedio-vestibular joint occurred in the process of mobilization, but it was possible to mobilize the stapes in only a relatively small percentage of cases

TABLE I

	Force Applied to Neck of Stapes	Force Applied Directly to Footplate
Number of Cases	100	100
Immediate Improvement	35	72
Improvement Maintained		
One Month	30	64
Four Months	29	55
One Year	24	Not available

It is reasonable to assume that all cases which would have terminated successfully by early techniques would also be successful when the mobilizing force is applied at the footplate In this study there were many more cases from Classes II and III which required more extensive surgery at the footplate and crura before an improvement in hearing was obtained This additional manipulation without the loss of ossicular continuity doubtlessly accounts for the higher percentage of good initial results It appears reasonable that a larger percentage of cases would return to the preoperative level in the immediate postoperative period as mobilization of

4 The surgeon must constantly keep in mind that in the course of mobilization of the footplate, penetrations, fenestration or dehiscence produced in this structure will only add risks which may reduce the quality of the final result

5 The surgeon need not feel obliged to achieve mobilization of the footplate at any cost Cases presenting very advanced otosclerosis or difficult anatomy should be recognized as unfavorable for the mobilization operation and should be spared for fenestration of the horizontal canal

CONCLUSIONS

The use of the surgical microscope adds considerable safety to the mobilization of the stapes operation, as it permits direct visualization of the otosclerotic involvement, better control of the forces required for mobilization and precise notation of the changes produced by the applied forces

It is possible to differentiate four classes of otosclerotic involvement on an anatomic and pathologic basis which can serve as a guide for the choice of a suitable mobilization technique In order to apply this classification to any case, careful study is necessary before mobilization is attempted This pre-mobilization evaluation, together with a suitable mobilization technique, has been responsible in producing a high percentage of good results with few complications

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162 East 71st Street

Gelfoam saturated in thrombin, as this tends to reduce the postoperative vertigo Uncovered perforations of the footplate are usaully productive of more vertigo and instability of longer duration

As experience is obtained with mobilization techniques at the footplate, vertigo is observed less frequently In the last 50 patients of a more recent series of cases only 12 per cent have experienced vertigo due to manipulation at the time of surgery All 50 patients were discharged from the hospital 24 hours after surgery without any evidence of vertigo At the present time the great majority of patients do not experience vertigo during the mobilization procedure, and when vertigo does occur it is mild and disappears before the patient leaves the operating room

COMMENTS

Blind application of the mobilizing force to the footplate of the stapes is considered to be a dangerous and bold procedure, as penetration into the vestibule cannot be prevented by the sense of touch alone The mobilization of the stapes must be considered strictly an external labyrinthine operation in which any instrumentation penetrating deeper than the footplate exposes the end-organs of hearing and equilibrium to trauma, serous and possibly purulent labyrinthitis The objective of all techniques at the footplate of the stapes is to achieve mobility with absolutely no penetration into the vestibule and with the least possible surgical trauma

The techniques described above tend to emphasize the importance of the following aspects of stapedial footplate surgery

1 The area of the footplate which is to receive the mobilizing force must be seen directly under high magnification

2 All manipulation is done with extreme gentleness, slowly and cautiously until the character, position and extent of the otosclerotic lesion are appreciated

3 When the area of fixation is located the choice of mobilization procedure is made in accordance with the four classes of otosclerotic involvement presented in this study in the left ear for the past four to five months About one week before the patient was first seen he described the left ear as feeling full It was at this time that he put his finger to the left ear and caused bleeding He immediately consulted a physician who visualized a tumor mass in the left external auditory canal and took a specimen of the mass for histological examination The patient denied any previous history of pain in the ear and was not aware of any discharge from the ear Two days before he was seen he noticed a numb sensation over the left side of his face and found that he could not completely close his left eye nor could he move the left corner of his mouth normally

Physical examination at this time revealed a middle-aged man with an obvious facial paralysis The paralysis was peripheral in type and not

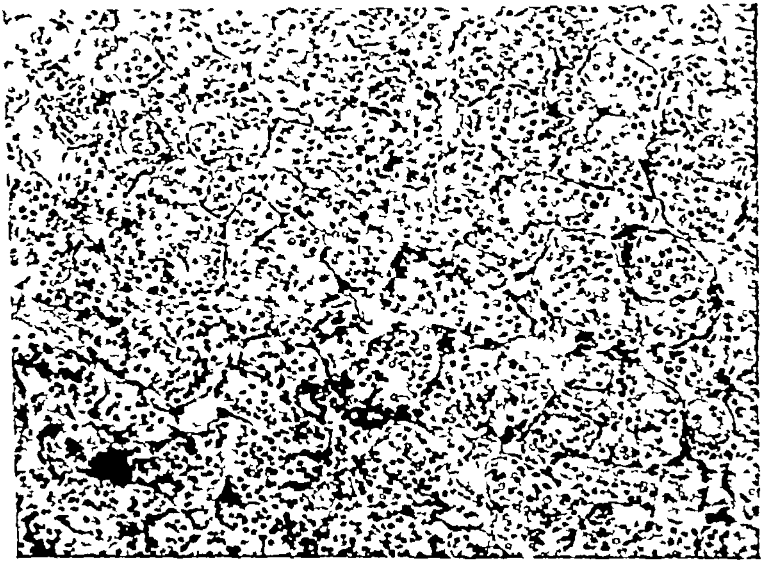

Fig 1 A representative section from a histologically benign glomus jugulare tumor showing the regular arrangement of the cells and the lack of mitotic activity

complete as there was still slight motion at the corner of the mouth on the left. The other positive findings were limited to the left ear There was a tumor mass occupying the inner half of the left external auditory canal and the tympanic membrane could not be visualized Roentgenological examination of the mastoids revealed minimal sclerosis of the cells of the left mastoid however no other abnormality of the left temporal bone could be identified The Weber test was strongly lateralized to the left. Pure tone audiometry revealed responses within normal limits for the right ear Losses averaging 40 db in the speech frequencies by air conduction were obtained in the left ear with good preservation of bone conduction Speech testing revealed a speech reception threshold of 40 db in the left ear with a discrimination score of 88 per cent. Histological examination of the tissue which had been removed previously was reported to show a very highly vascular malignant tumor with cells having

HISTOLOGICALLY MALIGNANT GLOMUS JUGULARE TUMOR (Case Report)

GORDON D. HOOPLE, M.D.,
WESLEY H. BRADLEY, M.D.,
LEE R. STONER, M.D.,
and
DAVID W. BREWER, M.D.,

Syracuse, N.Y.

In the decade since Rosenwasser first correlated the clinical findings of glomus jugulare tumor with Guild's previously published anatomical description of the glomus jugulare bodies, numerous examples of this neoplasm have been reported. Interest has not been limited to the otological literature alone, as excellent reports have also appeared in the journals of pathology and neuro-surgery.

There has been general agreement among authors that these neoplasms should be classified as histologically benign lesions (see Fig. 1). Their clinical behavior with the typical history of slowly developing symptoms, often over a period of years, would substantiate this assumption; however, their tendency to invade adjacent vital structures with the development of vascular or neurologic involvement threatening the patient's life, has led some authors to describe these lesions as histologically benign, but locally malignant by position. Metastatic spread from a primary glomus jugulare tumor has been reported only infrequently.[1,2,3,4]

This case report of a patient with a glomus jugulare tumor described as histologically malignant is added to the literature because of the infrequency of such a lesion.

CASE REPORT

This 49 year old white male was first seen on February 10, 1956 with a chief complaint of bleeding from his left ear of about one week's duration. The present illness revealed that he had noticed increasing hearing loss

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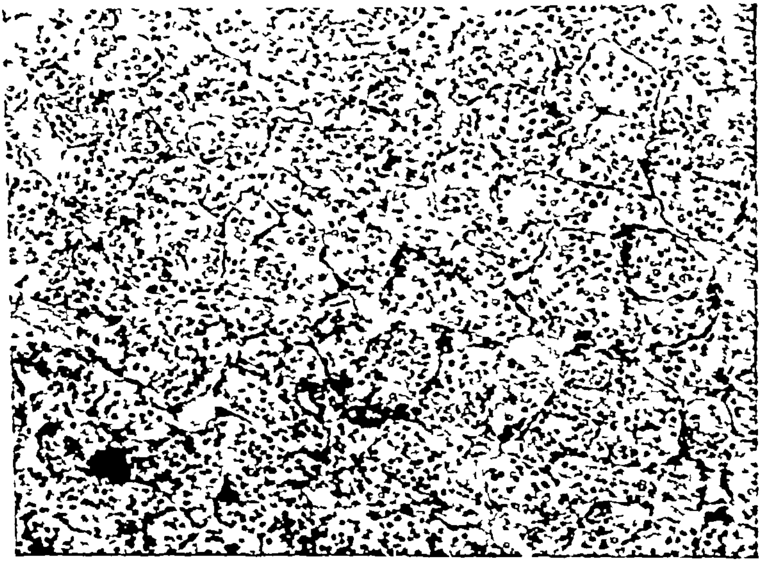

Fig 1. A representative section from a histologically benign glomus jugulare tumor showing the regular arrangement of the cells and the lack of mitotic activity

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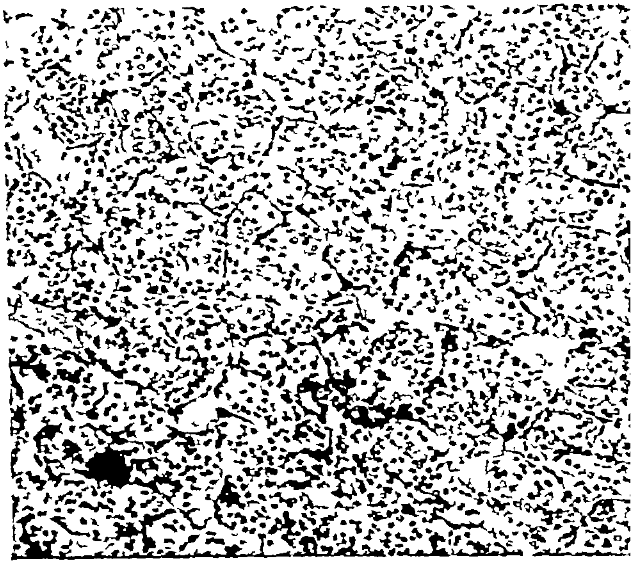

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HISTOLOGICALLY MALIGNANT GLOMUS JUGULARE TUMOR (Case Report)

GORDON D HOOPLE, M D ,
WESLEY H BRADLEY, M D ,
LEE R STONER, M D ,
and
DAVID W BREWER, M D ,
Syracuse, N Y

In the decade since Rosenwasser first correlated the clinical findings of glomus jugulare tumor with Guild's previously published anatomical description of the glomus jugulare bodies, numerous examples of this neoplasm have been reported Interest has not been limited to the otological literature alone, as excellent reports have also appeared in the journals of pathology and neuro-surgery

There has been general agreement among authors that these neoplasms should be classified as histologically benign lesions (see Fig 1) Their clinical behavior with the typical history of slowly developing symptoms, often over a period of years, would substantiate this assumption, however, their tendency to invade adjacent vital structures with the development of vascular or neurologic involvement threatening the patient's life, has led some authors to describe these lesions as histologically benign, but locally malignant by position Metastatic spread from a primary glomus jugulare tumor has been reported only infrequently[1,2,3,4]

This case report of a patient with a glomus jugulare tumor described as histologically malignant is added to the literature because of the infrequency of such a lesion

CASE REPORT

This 49 year old white male was first seen on February 10 1956 with a chief complaint of bleeding from his left ear, of about one week's duration The present illness revealed that he had noticed increasing hearing loss

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7 The facial nerve was exposed in the anterior half of its intra tympanic segment

At the completion of surgery the cavity was relatively clean, but it was obviously realized that residual tumor had been left.

Post-operatively the patient did well and the facial paresis recovered in four days On February 24th he was started on external irradiation therapy to the left temporal bone He received approximately 3 000 roentgens over a period of three weeks

During the period of irradiation his cavity seemed to heal surprisingly well however by the time his therapy was completed a very obvious drooping of his dura had developed. Posteriorly in the bowl the dura rested almost on the facial ridge On May 2 1956 the patient had a convulsion lasting a few minutes On May 28 1956 he had a sudden hemorrhage from his left ear On June 8 1956 a return of tumor tissue in the region of the tympanum was noted On June 12 an anterior cervical node was palpated just behind the angle of the mandible. Chest X rays at this time revealed multiple metastases throughout both lung fields. His downward course following this was very rapid with increase in the involvement in the neck, the development of aphasia and finally paralysis of the right arm and leg The patient expired July 17th approximately five months after he was first seen

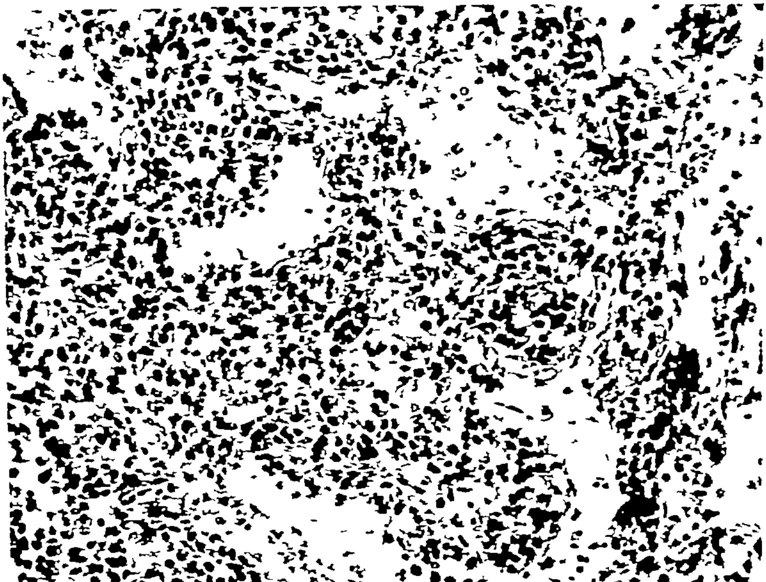

Fig 3 A representative section of the pulmonary metastases showing similar tumor tissue with a small amount of normal lung tissue still identifiable

perivascular arrangement consistent with malignant glomus jugulare tumor (see Fig 2)

On February 14 1956, left radical mastoidectomy was carried out The following interesting findings were noted at surgery

1 There was already tumor involvement of the bone of the posterior superior canal wall with tumor tissue presenting through the bone

2 Cells of the superior half of the mastoid were diseased and filled with tumor tissue while the cells of the lower half of the mastoid including the tip were clear

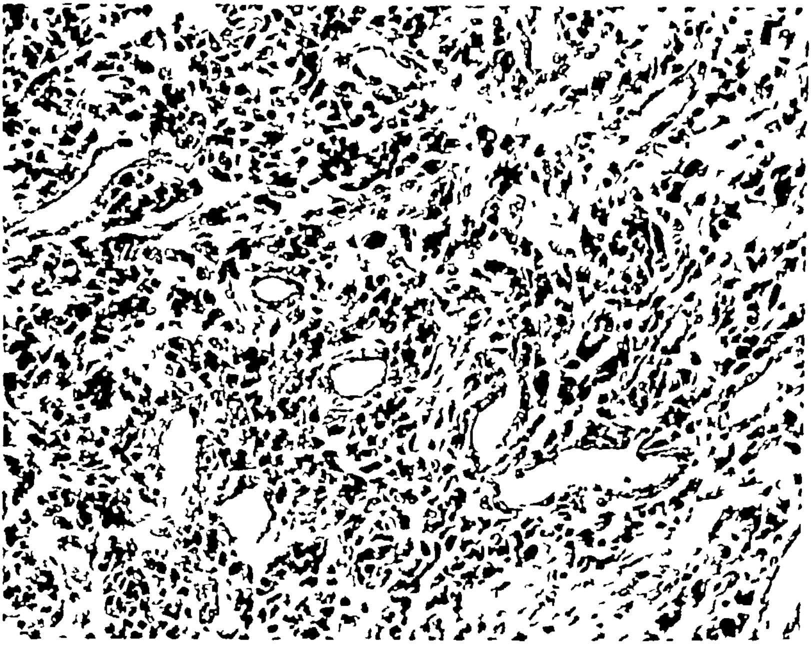

Fig 2 A representative section of the main tumor mass showing the lack of regular cellular arrangement the lack of polarity of the cells and the increase in mitotic activity

3 The lateral sinus was pathologically exposed and there was tumor tissue on the wall of the sinus

4 The dura was exposed over the tegmen antri for an area approximately 2 5 cm x 1 5 cm and this dura was involved with tumor tissue

5 When the main mass of tumor was removed from the tympanum along with the remnants of the drum the stapes was visualized still present in the oval window with tumor tissue surrounding it

6 Anterior to the labyrinth the removal of tumor tissue furnished a lead into the petrous pyramid The entire pyramid was filled with tumor tissue and the superior wall was gone leaving the dura in the area completely exposed

7 The facial nerve was exposed in the anterior half of its intra tympanic segment

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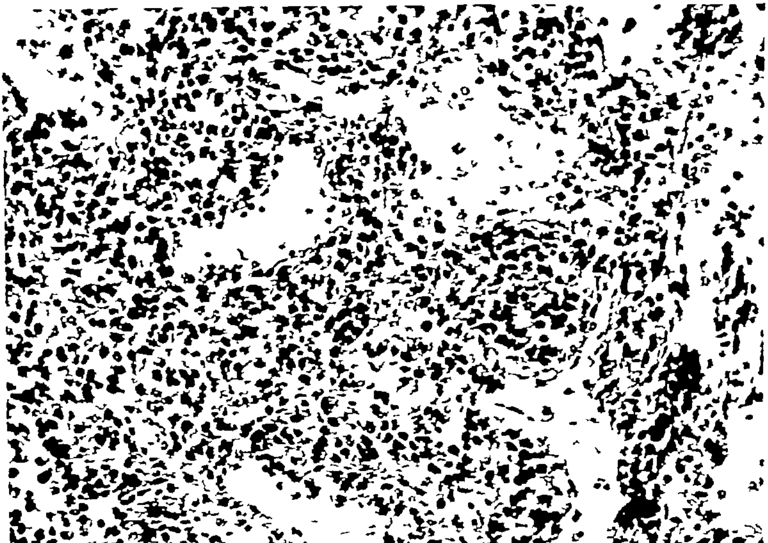

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Post-mortem examination was carried out and revealed the following

1 The lungs revealed multiple foci of metastatic tumor (see Fig 3)

2 The left temporal bone and brain revealed highly anaplastic and vascular malignancy with marked infiltrative tendencies There was extension throughout the petrous portion of temporal bone with dural breakthrough Direct extension to the brain in the left temporal lobe and throughout the subarachnoid space in the posterior fossa was present

The pathological diagnosis was

1 Malignant left glomus jugulare tumor with pulmonary metastasis

2 Diffuse infiltration of the left temporal bone with mastoid replacement

3 Mastoiditis and dural invasion with meningitis and direct cerebral extension

The summary of the pathologist was as follows "This rather unusual diagnosis is based on the combined pathological and clinical findings Pathologically, the topography, histology, and cytology are entirely consistent with what has been described Clinically, the localization and progression of the disease tend to confirm the findings of a primary tumor of the left temporal bone with a highly malignant potential"

DISCUSSION

It would appear that the clinical course of this patient substantiates the histological diagnosis of a malignant lesion The rapid downhill course described above is not the typical story of a glomus jugulare tumor We have previously seen patients with equally as much or more tumor involvement who have survived without serious difficulty for a period of years, some of them with little treatment The rapid return of the lesion after surgery and its spread both locally and to distant sites are far more characteristic of a highly anaplastic squamous cell carcinoma of the middle ear

The above case history should again emphasize the fact that although these lesions are usually considered to be benign, malignant variants can and do occur With the extensive involvement which was present in this case, it was obvious that complete surgical extirpation could not be achieved Irradiation therapy did not seem to offer any additional help Whether newer techniques with irradiation therapy will offer more promising results in the future, only time can tell At this time, however, we feel we must concede that the outlook with a malignant form of glomus jugulare tumor remains pessimistic

SUMMARY

One case of histologically proven malignant glomus jugulare tumor has been presented

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COURS DE TECHNIQUE CHIRURGICALS

The Faculty of Medicine of Paris, Chaire de Clinique Oto-Rhino-Laryngologique under the direction of Professor A. Aubin will present a course in the Surgery of Deafness, June 9-14, 1958

CONTROVERSIAL ASPECTS OF THE TREATMENT OF LARYNGEAL KERATOSIS[*][†]

ROBERT E PRIEST, M D ,

Minneapolis, Minn

This paper sets forth some personal experiences in the treatment of recurrent severe laryngeal keratosis, reviews the reports of others, and is written to focus attention on the problem of the treatment of severe recurrent keratosis or leukoplakia of the vocal cords In it, no attempt is made to review a large series of cases, or to draw statistical conclusions, the discussion does not pertain to mild nor non-recurrent keratosis The problem is presented from the standpoint of one clinician who is troubled by a difficult problem, of serious portent to his patients, for which only an incomplete solution exists Case summaries illustrate some of the various clinical sequences encountered, *i e*, *(a)* Keratosis with quick metamorphosis into carcinoma leading to laryngectomy *(Case 1)*, *(b)* Keratosis with long interval before becoming invasive and needing laryngectomy *(Case 2)*, *(c)* Keratosis observed for many years, treated by radiation and local excision, and after many years still apparently controlled *(Case 4)*

A recent experience in which I recommended irradiation therapy for a man having recurrent laryngeal keratosis, and the local radiologist refused to treat him, has served to make me examine carefully the various aspects and ramifications of this subject A few months ago, I removed a large keratosis from the larynx of a 74-year-old man *(Case 3)*, five years after removing a similar keratosis from his larynx The patient weighed 260 pounds, was not a good surgical candidate, and I asked his family doctor, at a considerable

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[†] From the Division of Otolaryngology of the University of Minnesota Medical School Minneapolis Minn

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distance from Minneapolis, to arrange for radiation therapy near his home I explained to the local physician that the patient's lesion was precancerous, and that I hoped that radiation would prevent later development of a cancer The local physician took the matter up with the local radiologist and others, and the collective decision was that inasmuch as the lesion was not malignant, it should not be radiated I wondered whether I had been wrong in recommending radiation for a non-cancerous lesion, and consulted with my colleagues and read what I could find on the subject, then the patient was brought to Minneapolis, where he was subjected to a full cancercidal dose of deep X-ray therapy, fractionally administered, at the University of Minnesota Hospitals Radiation

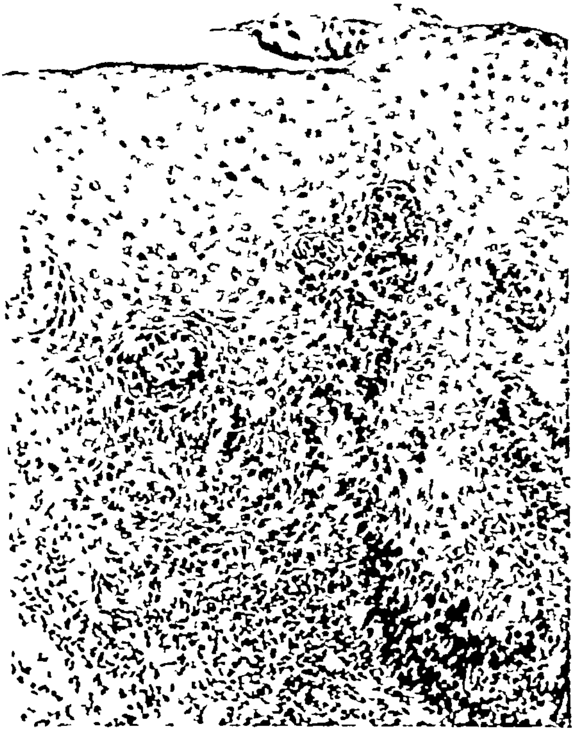

Fig 1 Case 1 Dec 7 1949 Biopsy of right vocal cord interpreted as keratosis but subsequently re-evaluated as indicating carcinoma

was prescribed here partly because of the experiences outlined below

In 1949 and 1950, I removed keratotic masses from the larynx of a 59-year-old man *(Case 1)* In 1951, a biopsy showed low grade malignancy and the larynx was removed *(Case 1,* see Figs 1, 2 and 3) This lesion progressed from keratosis to carcinoma in two years This is somewhat similar to a case cited by Jackson,[1] and is an unhappy sequence which must have been encountered by many other physicians

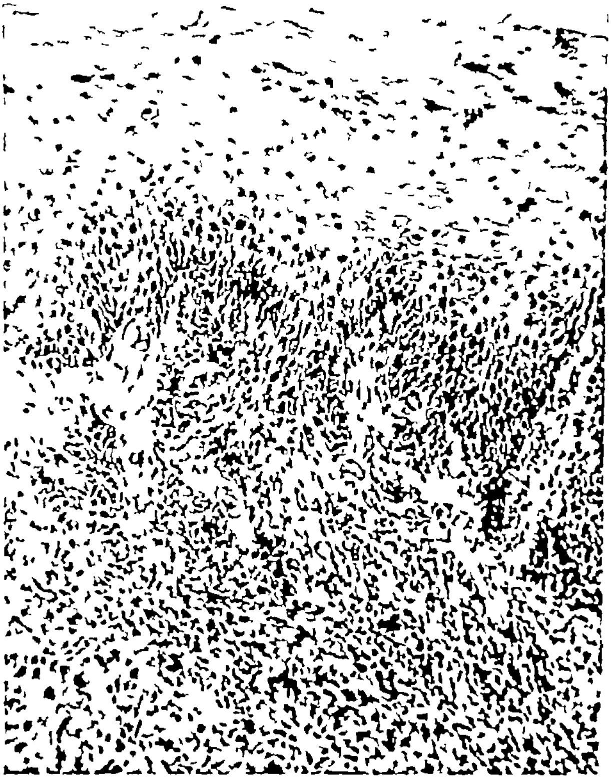

Fig 2 Case 1 Jun 11 1950 Biopsy of right vocal cord and misinterpreted as was Fig 1

Shortly after this unpleasant experience another patient *(Case 2)* with an extensive laryngeal keratosis, came to me for advice This man had been told elsewhere to have a laryngectomy on the basis of a frozen section interpreted as indicating cancer My biopsy showed no cancer in the opinion of several competent pathologists (see Fig 4) I thought about the patient described above, whose keratosis I had removed repeatedly and who had developed cancer requiring laryngectomy It seemed to me that there must be a better way to treat this condition than simply to remove keratoses repeatedly I thought that any patient who developed vocal cord cancer after precancerous lesions had been excised from his cords repeatedly, would surely have a right to wonder whether his doctor had treated him in the most effective manner It seemed that the doctor should critically examine his therapeutic method

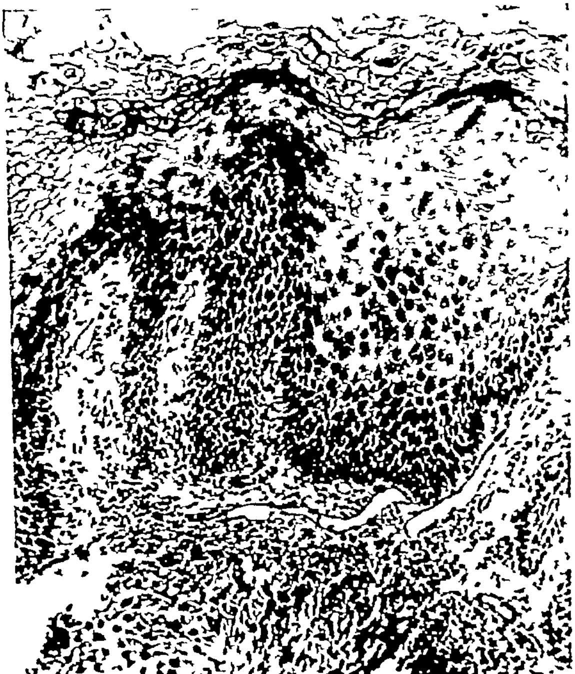

Fig 3 Case 1. Sept. 1950 Biopsy of right vocal cord misinterpreted as in Figs 1 and 2 but re-evaluated as indicating carcinoma and followed by laryngectomy with apparent cure

Schall[2] had shown that radiation produced five-year cures in 92 per cent of small cordal epitheliomas, however, I knew that radiation reduced the viability of tissues If surgery was needed later, this certainly would have to be taken into account My memory of pharyngostomes, shown to me by Dr Walter Work at The Veterans' Hospital in San Francisco, was vivid These gaping holes had resulted from poor wound healing in patients having laryngectomy after radiation had failed to cure their laryngeal cancers

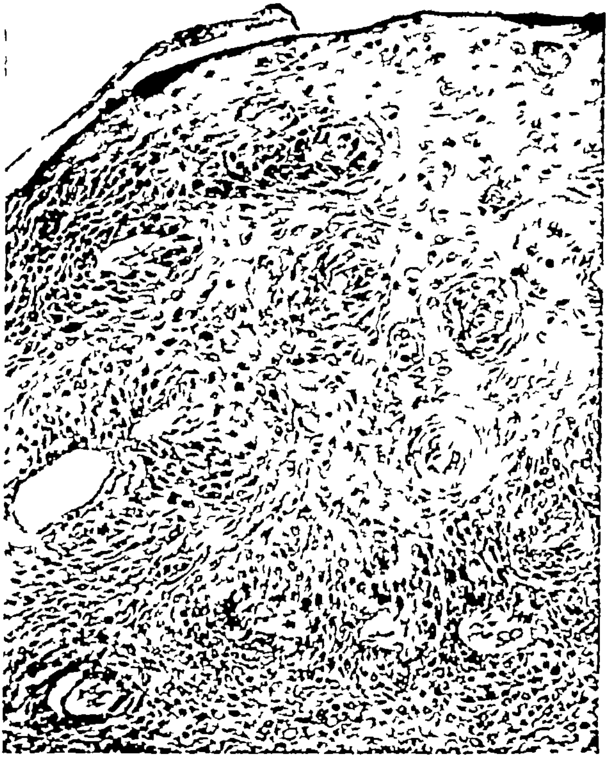

Fig 4 Case 2 July 17 1952 Biopsy of right vocal cord interpreted as indication keratosis and no carcinoma Cords then stripped of keratosis (July 21 1952) Patient subjected to repeated biopsies and X-ray therapy to larynx In 1957 biopsy showed carcinoma and laryngectomy was done

In considering Case 2, I telephoned to one of the country's most eminent laryngologists in another city and discussed the problem with him He said that he had been through the same series of experiences, and had used X-ray therapy to treat patients with recurrent laryngeal keratosis in a small number of cases with seemingly good results, therefore the patient who had been advised elsewhere to have a laryngectomy (Case 2) was treated by stripping his cords completely of keratosis, and the larynx was radiated with deep

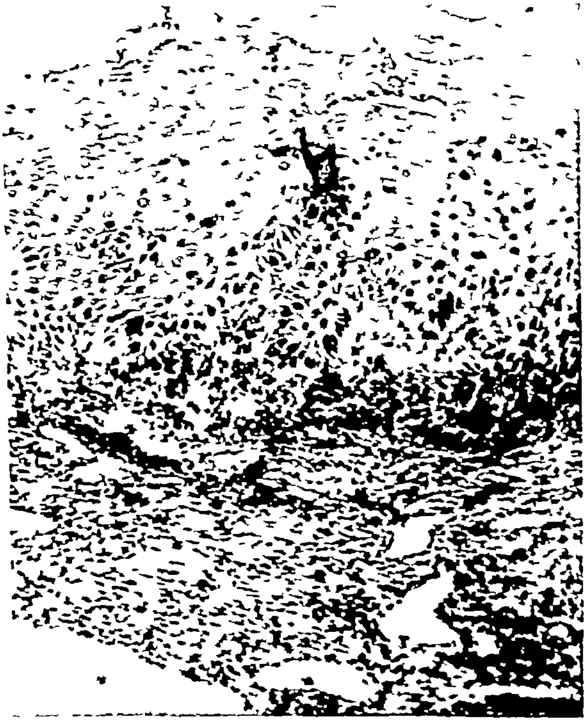

Fig 5 Case 3 July 1952 Biopsy of left cord in 69-year-old male interpreted as keratosis See Fig 6 for biopsy of same case five years later

X-ray The keratosis seemed to regress, and in 1955, three years after the first biopsy, a specimen was presented at the University of Minnesota's pathologists' conference This conference is attended by pathologists from some 20 hospitals in Minneapolis and St Paul These men could see no difference in slides made in 1955 and those in 1952 They did not rule out a diagnosis of pre-invasive carcinoma, but thought one could classify the lesion as keratosis or leukoplakia with equal accuracy

From 1955 to 1957 repeated biopsies showed no change, but in 1957 an invasive carcinoma of the vocal cord was diagnosed and the larynx removed The histories of Casses 1, 2, 3 and 4 are summarized at the end of the paper and photomicrographs of their laryngeal biopsies are presented there (see Figs 1 through 9)

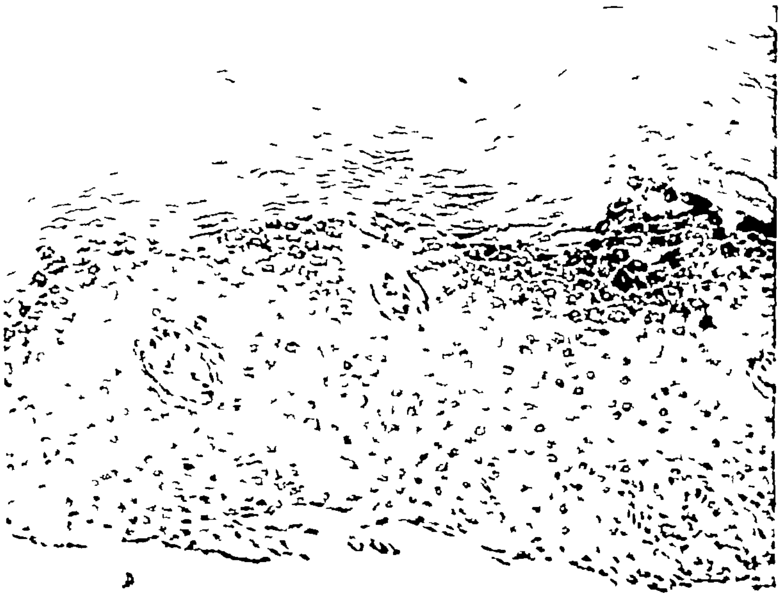

Fig 6 Case 3 April 25 1957 Biopsy of right cord for recurrence of keratosis illustrated in Fig 5 Locally excised and later treated by full cancercidal dose of deep X-ray

In treating leukoplakia or keratosis or carcinoma *in situ* of the vocal cords, the laryngologist is dependent upon the pathologist's interpretation of the biopsy and his general attitude as well as his nomenclature and classification In Case 1 cited above, the original reports by the pathologist examining biopsy specimens indicated no invasive tendency on the part of the tumor, after the larynx had been removed for cancer, re-examination of the original slides by another pathologist showed that the invasive tendency could occasionally be demonstrated (see Fig 1) It is easy for the pathologist to tell frankly invasive cells from frankly non-invasive cells in epithelial biopsies, but to be sure when the lesser degrees of invasiveness appear is difficult The sections examined cannot represent the entire specimen, and the pathologist's philosophy, astuteness, nomenclature and breadth of experience all influence his report

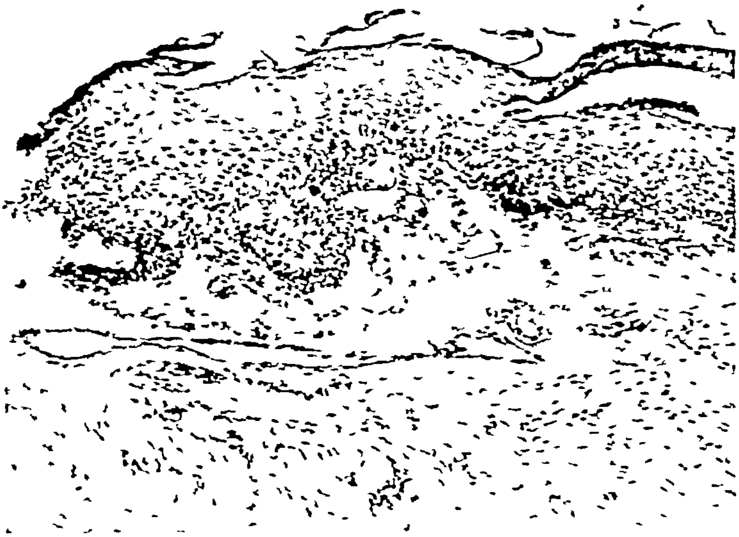

Fig 7 Case 4 1949 Biopsy of right and left vocal cords yielded tissue of this type interpreted as keratosis Deep X-ray therapy to larynx in 1952 Recurrences thereafter were limited to one small area of left cord. See Figs 8 and 9 for tissue taken seven and eight years later

Park and Lees[8] say that the pathologist, when he is at all uncertain, must play safe and make a "pragmatic" diagnosis of malignancy They cite urologic pathologists who say that intramucosal carcinoma of the prostate is present in 12 to 40 per cent of males after the age of 50 years despite the fact that the death rate from this disease is only about 1 per cent of the deaths of all males This example illustrates the present discrepancy between the morphologic definition of carcinoma and some clinical realities

The terms leukoplakia, carcinoma *in situ*, incipient carcinoma, preinvasive carcinoma, intramucosal carcinoma and superficial non-invasive intra-epithelial carcinoma are encountered in a discussion by Hertig and Younge[6] relating to carcinoma of the uterine cervix These authors say that the concept has been advanced that carcinoma *in situ* in an early

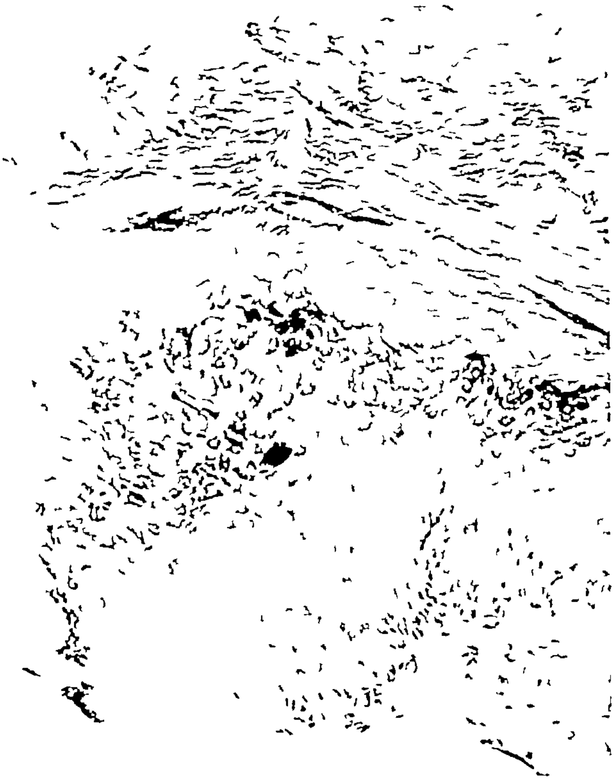

Fig 8 Case 4 1956 Similar to Fig 7

stage of invasive carcinoma, and will become invasive cancer if one only waits long enough Cases are cited in which the metamorphosis occurred in 11 months to 13 years The authors admit the possibility that invasion may have been present at the time of the original biopsy, but point out that the entire cervix would have to be sectioned to decide this Thus they say "the absolute scientific proof that the *in situ* stage of carcinoma precedes the invasive stage may never be forthcoming, since to rule out early invasion one must have the entire cervix, but to prove the ultimate invasiveness of the process the cervix must be left in"

Jones[7] described 740 patients having carcinoma of the uterine cervix Of these it was found that 13 had happened to have biopsies made one to 17 years earlier, all interpreted as being non-malignant In 12 of the 13 re-examinations of the original specimens showed squamous epithelium, and in 11 of the 12 intraepithelial carcinoma was present Jones said, "We therefore came to the conclusion that most individuals with clinical carcinoma of the cervix have a preceding lesion which we call 'intraepithelial carcinoma'"

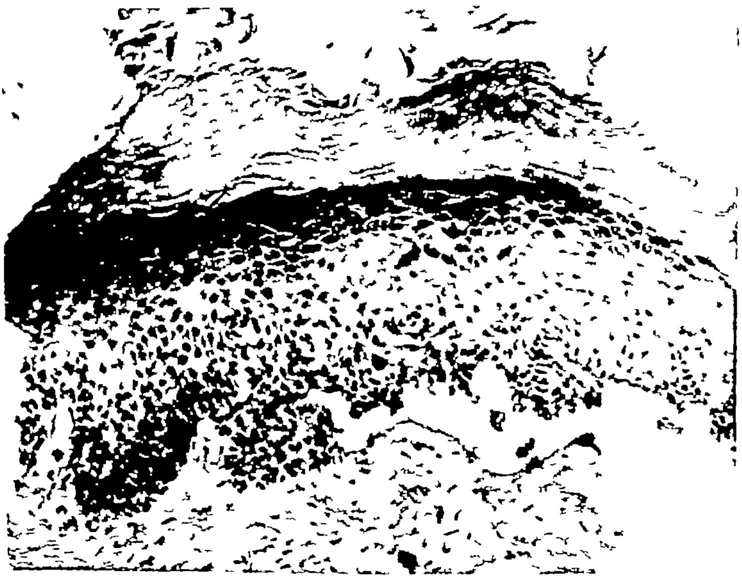

Fig 9 Case 4 1957 Similar to Figs 7 and 8 Locally removed and base cauterized with electrocoagulation

Putney and O'Keefe[3] in 1953 reviewed 125 cases of laryngeal keratosis, and said that keratosis of the larynx was a premalignant lesion in a definite percentage of cases when it persists In their cases carcinoma supervened in less than six months after the first biopsy in six cases, and only after eight to ten years in three cases, 41 never showed malignant degeneration Putney and O'Keefe emphasize the need for repeated histologic examination of keratotic lesions of the vocal cords for accurate diagnosis Putney[4] in 1955 commented further on these cases and others He said that benign histologic appearance is not proof that the lesion will remain benign He thought that management is not simple and includes forceps removal, X-ray therapy, excision by thyrotomy approach, irradiation by suspension laryngoscopy and electro-surgical removal of the lesion

Miller and Fisher[5] feel that carcinoma *in situ* in the larynx is an early pre-invasive stage of intra-epithelial carcinoma In their series, deep X-ray radiation was given to ten patients, the superficial lesion being stripped away in seven In seven of the ten cases, the lesion appeared to be controlled five-and-a-half to 53 months after treatment Recurrences after six and 16 months respectively in two patients were treated by endolaryngeal removal of the lesions without further recurrence Two patients were treated by laryngofissure only and were still controlled 31 and 16 months later Stripping alone was done in one patient whose larynx remained normal for 18 months This study showed that carcinoma *in situ* of the larynx can be treated by X-ray but may recur

Comment The laryngologist treating keratosis of the vocal cord faces a complex problem Perhaps the concept that keratosis or carcinoma *in situ* will surely become malignant if allowed to develop unchanged is true for many cases If so, what can be done to interrupt this metamorphosis? Aside from various forms of mechanical treatment, irradiation is the most important agent available Unfortunately, no chemical agents seem to exist at this time which upset the change of cells from the normal to the malignant state Parenthetically, I may say here that I once treated several laryngeal squamous cancers in males with female hormones, because of the predilection of this disease for males, with no discernible result The question of the influence of radiation therapy on *in situ* carcinoma is important The fundamental question is can radiation therapy influence potentially invasive epithelial cells, already morphologically different from normal but not yet different enough to be invasive, so that their invasive tendencies will be destroyed? Case 2, cited above, had the use of his larynx for six years after radiation but developed cancer despite radiation Whether his cell metamorphosis was slowed down by the radiation is a matter of opinion

The sum total of published experience on this subject appears to be insufficient to permit an absolute conclusion at this time, however, if real vocal cord cancers can sometimes be cured by radiation, when they are not far advanced (Schall[2]), does it not seem possible that recurrent leukoplakia may be discouraged in its progress toward invasive carcinoma by radiation therapy? It is reasonable to hope that in some cases malignant metamorphosis will cease or be slowed down. *The purists will argue that those cases which do not become* malignant were not really potentially malignant anyhow, and nobody can say that they are wrong Use of radiation therapy for treatment of recurrent severe laryngeal keratosis at present is empirical In severe recurrent keratosis it seems to me to be better than simple mechanical removal alone, but in cases of localized keratosis, not superior to local excision and electrocoagulation The treatment of laryngeal keratosis must be individualized in each case, and an open-minded attitude must be maintained by the clinician, to permit the use of several different therapeutic methods in any one case Radiation may be used in conjunction with local excision and/or electrocoagulation

It appears that severe recurrent laryngeal keratosis, like uterine cervical keratosis, is probably a disease extending over a period of ten or more years, in which progress from non-invasive to invasive is inevitable Frequent inspection of the larynx and repeated biopsies to detect early change from non-invasive type to invasive are essential to the management of the disease.

ABSTRACTS OF CASES

Case 1 A.D No 6480 aged 59 was first examined because of hoarseness in December 1949 His right vocal cord was found to be completely covered with glistening white piled up epithelium. Biopsy Dec 7 1949 was reported as benign keratosis (see Fig. 1) On Jan 11 1950, 35 pieces were stripped from cord (see Fig 2) In September 1950 he eight to ten years in three cases, 41 never showed malignant degeneration Putney and O'Keefe emphasize the need for repeated histologic examination of keratotic lesions of the vocal cords for accurate diagnosis Putney[4] in 1955 commented further on these cases and others He said that benign histologic appearance is not proof that the lesion will remain benign He thought that management is not simple and includes forceps removal, X-ray therapy, excision by thyrotomy approach, irradiation by suspension laryngoscopy and electro-surgical removal of the lesion

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had recurrence of keratosis of right cord Seventeen pieces of tissue were removed from right cord and were reported as being keratosis and "no definite malignancy seen" Consultation with other pathologists indicated that malignancy was present (see Fig 3), and review of sections of previous biopsies showed that invasive tendency had probably been present all the time Laryngectomy was done on Oct 13, 1950, with apparent cure when patient was last examined in 1953

Case 2 E D S, No 11313, first examined in July, 1952 because of hoarseness He had been advised on basis of frozen section to have laryngectomy Pearly white lesions covered all of right cord and one third of left cord On July 17, 1952, biopsy (see Fig 4), no malignancy was found On July 21, 1952 thorough stripping of cord was done Patient was subjected to deep X ray therapy elsewhere probably receiving less than a cancercidal dose because he had previous radiation for another condition in his mandible Biopsies made in 1952 were called invasive but University of Minnesota pathologists thought they were non invasive Repeated biopsies were made elsewhere and in 1957 invasive tendencies were definitely found, and laryngectomy was done elsewhere

Case 3 F E, No 11347, aged 69 weight 260 lbs was first examined on July 19 1952, because of hoarseness, and was found to have a deep red lesion in the middle third of his left cord This was excised by direct laryngoscopy on July 21, 1952, in the belief that it was cancer Biopsy showed only keratosis (see Fig 5) The patient was instructed to return in two months He returned in five years! The lesion had recurred and had a red base and a keratotic grey surface but the cord still moved freely On April 25, 1957, local removal was done again with the mental reservation that this was cancer, and again the pathologic diagnosis was keratosis (see Fig 6) Radiation was recommended (Patient aged 74, weight 260 lbs), and the radiotherapist in the patient's home community refused to administer it on the ground that the lesion was non malignant Patient returned to Minneapolis and full cancercidal dose of Gamma radiation was fractionally administered to the larynx in October 1957 Obviously the long term result cannot be assessed at this time

Case 4 C W C, No 875 aged 49, was first examined in 1949 because of hoarseness Despite four weeks of vocal rest and cessation of work hoarseness persisted Gray masses partially covered each vocal cord These were biopsied (see Fig 7) and were keratosis The lesions were stripped off but recurred in 1950 and grew larger so that in 1952 deep X ray therapy in dosage just under a cancercidal dose, was administered to the larynx In 1953 a tiny keratotic plaque reappeared on the left cord This was observed through 1954 and 1955, biopsied in 1956 (see Fig 8) and in 1957 was removed (see Fig 9) Histologically it was still benign keratosis Electrocoagulation of the base at the last removal may prevent recurrence, but has reduced the quality of the voice Prior to radiation the keratoses occurred all over the vocal cords After radiation recurrence was limited to one small area on one cord Obviously this man may still develop laryngeal cancer but it seems quite likely that he would have developed it long ago without treatment

SUMMARY

Borderline malignant lesions of the larynx are discussed from the standpoints of personal experience and after review of pertinent papers The concept that the condition variously designated as intra-epithelial carcinoma, or keratosis, or carci-

noma *in situ* et al , progresses rather relentlessly from being non-invasive to being invasive over a period up to ten or more years is examined, and at least partially accepted as appearing to delineate the course of certain laryngeal lesions The similarity of behavior of laryngeal lesions and those of the uterine cervix is taken into account The possibility that Gamma radiation may be used to slow down or interrupt the progressive change of the tumor cells from non-invasive to invasive is discussed It appears that the use of such radiation, in conjunction with mechanical removal of the lesion may have value but is empirical, and its exact degree of usefulness is impossible to assess If one chooses to use radiation therapy he must take into account the possibility that wound healing in subsequent surgery may be interfered with to a substantial degree

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ATTICOMASTOIDECTOMY IN CHRONIC OTITIS MEDIA WITH CENTRAL PERFORATION[*][†]

ROBERT HENNER, M D ,
and
COLETTE JEANTET, M D ,

Chicago, Ill

This discussion concerns itself with those patients who have persistent aural discharge due to chronic suppurative otitis media in the presence of a central perforation

These patients experience discomfort mainly of a fetid discharge, however, they are commonly considered "safe" insofar as intracranial complications are concerned These standards of safety were established early in the history of otologic surgery, and were balanced against the known incidence of surgical complications of that period Present day otologic skills in microsurgery of the temporal bone and antibiotic therapy have yielded such a high degree of success that it seems advisable to re-evaluate cases of chronic otitis media with central perforation as to their relative innocence

It should be clearly understood that all methods of nonsurgical management should first be exhausted The majority of these patients will respond to local and parenteral antibiotic therapy, as well as the time honored treatment of granulation tissue by excision and/or cauterization Adenoidectomy, when indicated, and treatment of underlying sinusitis and nasopharyngitis, whether allergic or inflammatory, particularly in younger patients, are often effective adjunctive treatment

There remains a relatively small number of patients who in spite of all nonsurgical measures, continue to suppurate, perhaps due to irreversible mastoid and attic pathology In

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[†] University of Illinois College of Medicine Illinois Eye and Ear Infirmary

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addition, the so-called "safety" of chronic suppurative otitis media with a central perforation refers to the only occasional presence of bone erosion by cholesteatoma in central perforation Otologists have all observed lateral sinus phlebitis, extradural abscess, facial paralysis and even brain abscess and fulminating meningitis develop after years of quiescent suppuration as the result of an acute exacerbation in the absence of cholesteatoma, also despite its low incidence, cholesteatoma does occur in a small number of such cases It may be produced by metaplasia, or a previous attic perforation may heal and with the very next acute otitis media, a permanent central perforation with chronic suppuration may result, with cholesteatoma as a surprise surgical finding Because of the potential dangers of continued suppuration, and because of the socioeconomic disadvantage of continuous and malodorous discharge, we have performed surgical treatment in many such patients

It is of interest to note that no comparable instance of a complacent attitude to chronic suppurative disease exists for lesions elsewhere in the body, especially when one considers the vital centers involved in the temporal bone area

In such patients, we have over the past 23 years, attempted radical mastoidectomy or mastoidotympanectomy While this procedure was successful in controlling the disease, the hearing response was often poor It must be borne in mind that the ossicular chain in these patients was usually intact This was in contrast to the usual improvement of hearing after mastoidotympanectomy and grafting in patients who had extensive polyposis, ossicular erosion and cholesteatoma

During this period, we also attempted atticomastoidectomy with a fenestration type flap, or the Bondy type of modified radical mastoidectomy The healing result and cessation of discharge were gratifying, but the care of the mastoid cavity became a problem When we considered the small degree of mesotympanic and hypotympanic bone necrosis, and since many of these patients are young, and because of the experience of periossicular microsurgery gained from fenestration operations, we, therefore, decided to carry out complete mas-

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weekly for 6 to 12 weeks after dusting of the cavity with antibiotic powder This is continued until the wound heals by granulations which form from the antrum to the endaural incision We have chosen to present nine out of 24 cases They are considered representative and describe the procedure and its results

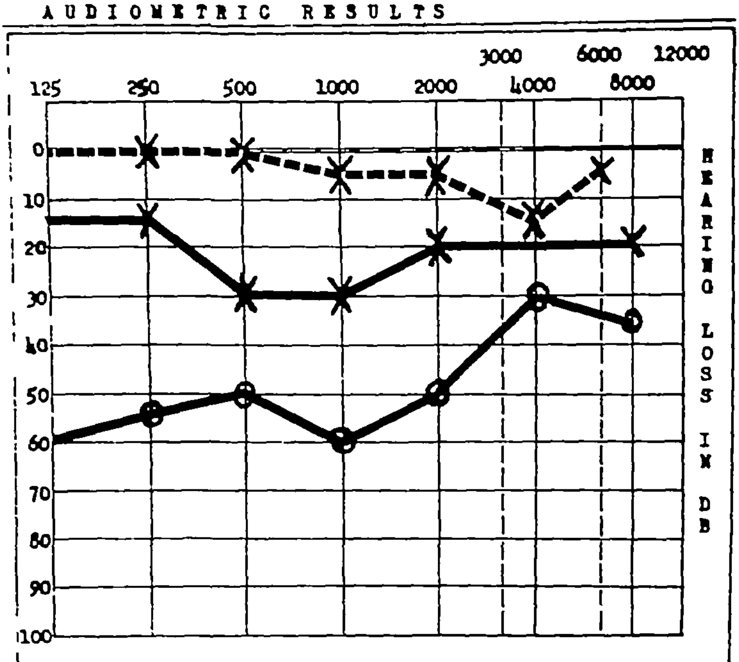

Fig. 2 D D male, Age 8, Date of Surgery 1/20/54

Case 1—M.A. Female age eight years first seen in November, 1952 with intermittent discharge from both ears for the past two years The family had noted some hearing loss T&A had been recently performed Examination showed severly retracted drums and evidence of secretory catarrh The child was treated repeatedly with antibiotics for recurrent episodes of pain and drainage. She underwent X ray therapy of the nasopharynx and a second adenoidectomy The right ear responded to these treatments and the hearing improved but the left ear developed a posterior and superior perforation with persistent discharge and averaged a 20 db loss

July 30 1953 an atticomastoidectomy was performed The mastoid showed mixed sclerosis and patches of granulation tissue with small areas of bone necrosis Under magnification granulation tissue was retoidectomy, including atticotomy, with careful skeletonization of the labyrinth, dural plate and ossicular chain This procedure is essentially an extensive simple mastoidectomy with addition of a complete atticotomy, preserving the posterior and superior bony canal wall It is performed endaurally so as to provide continuous access to the antrum for dusting with

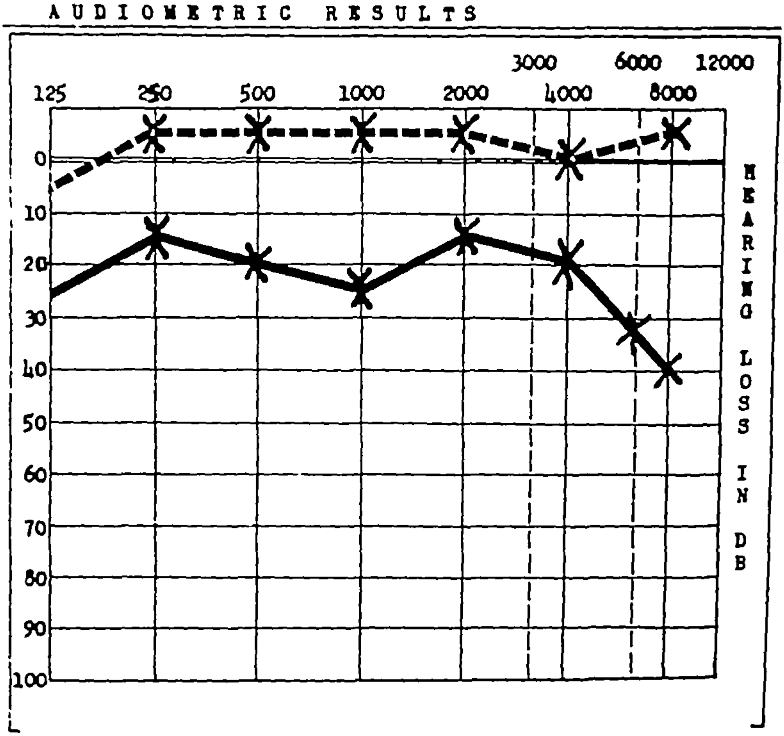

Fig 1 M A female, Age 8, Date of Surgery 7/30/53 Solid lines indicate preoperative hearing Dotted lines indicate postoperative hearing

antibiotic powder postoperatively If granulations of the hypotympanum and peritubal area are present, a 2 mm polishing bur is spun through the central perforation inferiorly and anteriorly toward the Eustachian tube At the time of surgery, the cavity is dusted with surgical aureomycin powder and the endaural incision closed with a polyethylene drain which leads to the antrum The drain is replaced tip and the retrofacial area These were filled with granulation tissue The attic was exposed and granulation tissue was dissected from the ossicles At the end of February 1954, the ear was healed and the hearing was practically normal by March 1954 The perforation closed spontaneously (Audiogram, see Fig 2)

Case 3—R. B Male age 23 first seen in March 1955, complaining of intermittent discharge from the left ear since childhood Examination showed a posterior central perforation with purulent drainage on the left side The patient had recently been treated extensively with antibiotics with each course of therapy the perforation would close and secretory otitis would ensue Paracentesis would be followed by a persistent discharge, again he was treated with antibiotics When this process had occurred four times with a hearing loss fluctuating around 30 to 35 db surgery was advised X rays of the mastoid revealed a marked disturbance of pneumatization one could see several medium sized clouded cells with thickened walls

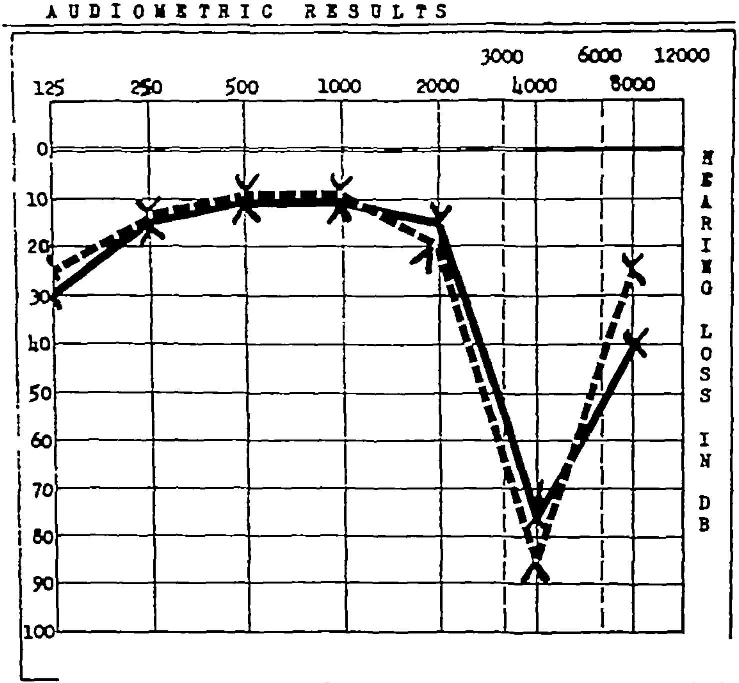

Fig 4 A. W female, Age 19, Date of Surgery 9/1/55

On March 29 1955 an atticomastoidectomy was performed There was necrosis of the mastoid cells and pus escaped under pressure Extensive granulations were found in the attic a periossicular dissection was carried out the tympanic perforation was freshened with a 1 mm.

moved from the attic and the ossicles were exposed and thoroughly cleaned

In September, 1953, healing was complete and hearing had returned to normal and has remained well (Audiogram, see Fig 1)

Case 2—D D, Male age eight years, first seen in October, 1953, with a history of bilateral ear infection at two months of age treated successfully with paracentesis and penicillin Three years prior to the first visit a recurrence of the infection had been again treated with penicillin followed by T&A but the left ear had continued draining intermittently ever since Examination showed a posterior central perforation of the left tympanic membrane with a protruding granuloma and purulent discharge The perforation healed after removal of the granuloma and local dusting with aureomycin powder, but the infection recurred in December 1953 again it responded well with local therapy only to flare up once more in January 1954 X rays showed a slightly underdeveloped left mastoid with patchy sclerosis and retrofacial and tip cells Hearing averaged 25 db loss in that ear Restoration of hearing was most important in this ear because of a congenital conductive loss of 30 db in the right ear

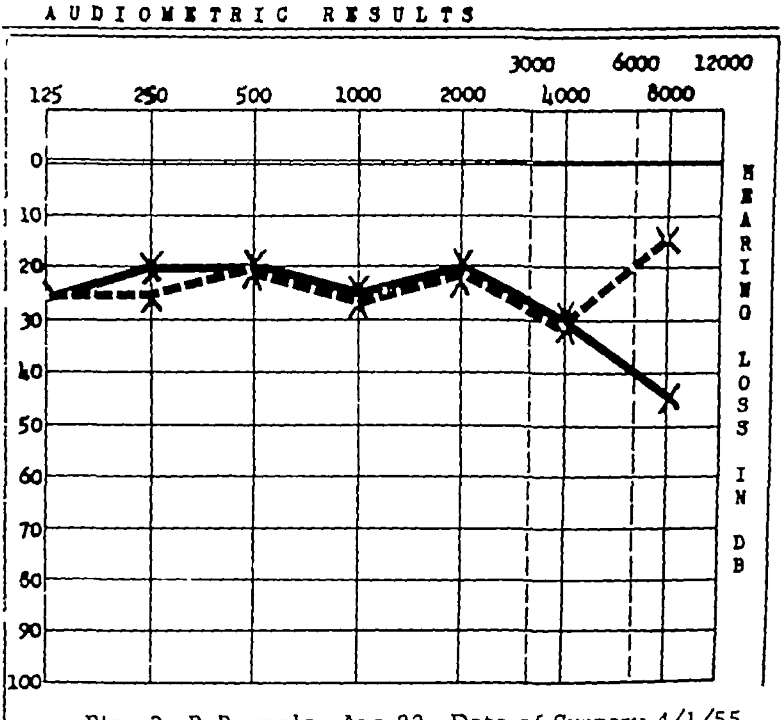

Fig 3 R B. male, Age 23, Date of Surgery 4/1/55

On January 20 1954 an atticomastoidectomy was performed The mastoid showed mixed sclerosis and cells were found only in the mastoid

Case 5—J A., Female, age 41, first seen in June 1956 with a history of repeated ear infections on the left side since 1927, the ear had been draining constantly for the past year The patient was complaining of headaches and tinnitus, repeated courses of antibiotics failed to cure the disease and her hearing loss averaged 40 db in the left ear

X rays of the mastoid showed a sclerosing mastoid bone and a few large cloudy perisinusal cells with thickened walls

An atticomastoidectomy was performed on July 10 1956 Chronic mastoiditis granulations of the attic and a pea sized cholesteatoma of the anterior attic recess were found and removed, the intact ossicles were left in place Healing was complete in September 1956 Post operatively her hearing improved to a 25 db level for the speech frequencies there has been no evidence of recurrence of the cholesteatoma and the patient will shortly undergo tympanoplasty (Audiogram see Fig 5)

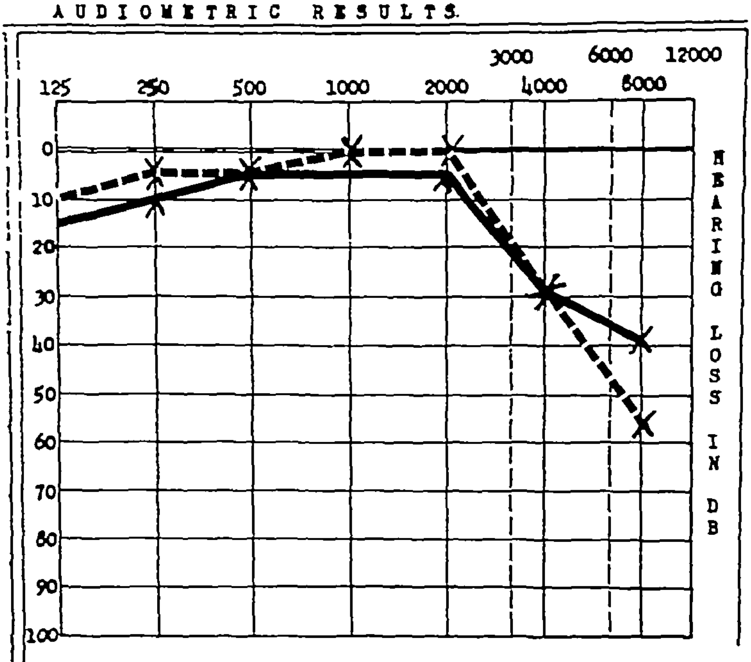

Fig 6 T R male, Age 11, Date of Surgery 1/16/57

Case 6—T R Male age 11 first seen in September 1956 with a history of intermittent discharge from both ears for the past eight years repeated antibiotic treatment had been unsuccessful, the adenoids had been twice removed Examination showed central perforations of both tympanic membranes with a purulent discharge the right ear responded to prolonged penicillin therapy (several courses of three to four weeks), polishing bur and closed with the triangular skinflap obtained from the endaural incision

May 27 1955 the drain was permanently removed in June the ear was dry and healed, the hearing averages 20 db (Audiogram see Fig 3)

Case 4—A W, Female age 19, first seen in August, 1955, complaining of intermittent pain and discharge from the left ear for several years Examination showed a granuloma on the posterior margin of the left drum with a purulent discharge and desquamative debris, several weeks of local and parenteral antibiotic care did not affect the persistent purulent discharge

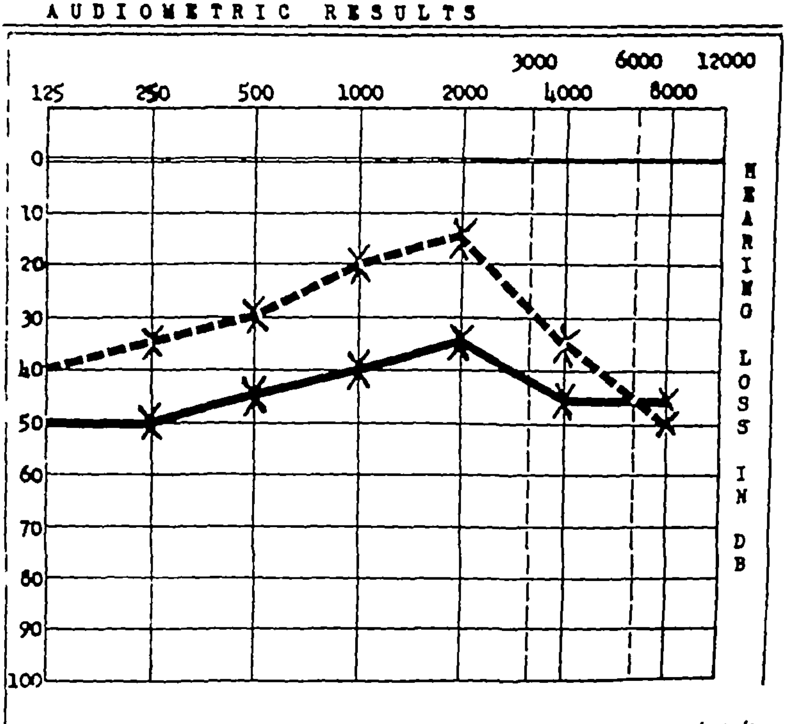

Fig 5 J A female, Age 41, Date of Surgery 7/10/56.

X rays revealed a sclerotic mastoid no isolated cells could be outlined her hearing averaged a 10 db loss for the speech range in this ear

Atticomastoidectomy was performed Sept 1, 1955 The ossicles were freed from a mass of granulations and left undisturbed The hypotympanum and peritubal granulations were removed with a polishing bur through the central perforation by the end of October the ear was dry but the perforation was still present In August 1956, the patient developed an acute infection of the operated ear following swimming The infection subsided under tetracycline therapy and the ear has been dry since Her hearing has returned to the preoperative level the perforation has persisted (Audiogram see Fig 4)

X rays of the left mastoid revealed patchy sclerosis with the exception of a few large clouded cells in the perisinus region, her hearing loss averaged 15 db An atticomastoidectomy was performed June 4 1957 Extensive granulations were found in the mastoid which was partially sclerosed, the few remaining cells contained a yellowish tenacious mucus, the granulations extending into the attic were dissected from the intact ossicular chain Our previously described postoperative care was given and in August the ear was dry currently an attempt is being made to close the perforation with trichloracetic acid applications and patching her hearing loss is 5 db (Audiogram, see Fig 7)

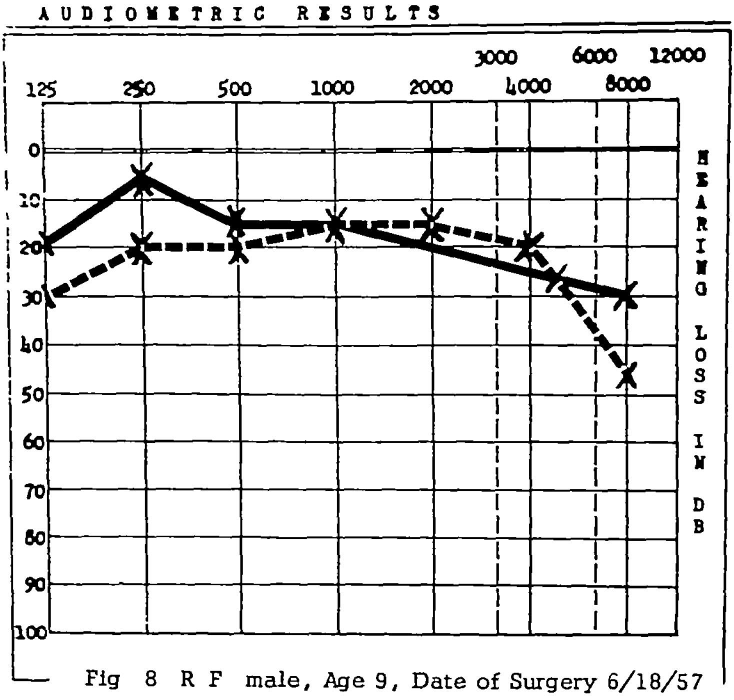

Fig 8 R F male, Age 9, Date of Surgery 6/18/57

Case 8—R F Male age 9 first seen in June 1957 with a history of an infection of the left ear when he was 3 years old resulting in a perforation with intermittent drainage the discharge became profuse several weeks prior to this first visit, although the patient had been on daily penicillin therapy for three years because of an erroneous diagnosis of rheumatic fever, the doses of penicillin had been increased and other antibiotics were added but failed to control the infection Examination of the left ear revealed a purulent exudate from a central perforation of the tympanic membrane. The hearing loss averaged 15 db in the speech range. X rays of the mastoid revealed a large cavity due to the confluence of several larger cells The trabeculation in the periantral region was indistinct with partial interruption and decalcification but the left ear continued draining, he was placed on sygmamycin therapy for two weeks without success

X rays of the left mastoid showed a disturbed pneumatization with lack of aeration, his hearing loss averaged 5 db in this ear On January 16, 1957, a left atticomastoidectomy was performed Granulations were removed from the perilabyrinthine area and the epitympanum On March 25, the drain was permanently removed and the middle ear has remained dry since A spontaneous closure of the perforation occurred in July There still was a dry perforation of the opposite drum this closed with trichloracetic acid applications The hearing in both ears now shows no loss (Audiogram, see Fig 6)

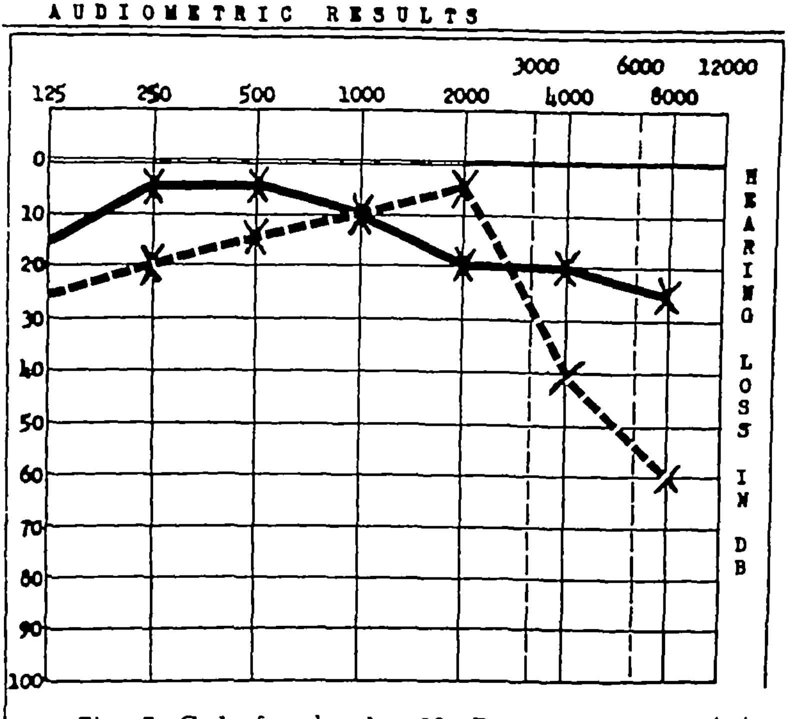

Fig 7 G A. female, Age 38, Date of Surgery 6/4/57

Case 7—G A Female age 38 first seen in February, 1957 with a history of bilateral ear infection at the age of 3 followed by a chronic discharge from both ears and a right mastoidectomy at the age of 19 This resulted in complete healing of the right ear, but with a residual hearing loss of 10 db The left ear had been draining intermittently and the patient had been aware of a recent increase of hearing loss on that side Examination showed a healed perforation of the right drum and a thick injected tympanic membrane on the left side with a small posterior central perforation and a mucopurulent discharge the infection responded well to prolonged tetracycline therapy but recurred shortly after cessation of the antibiotic

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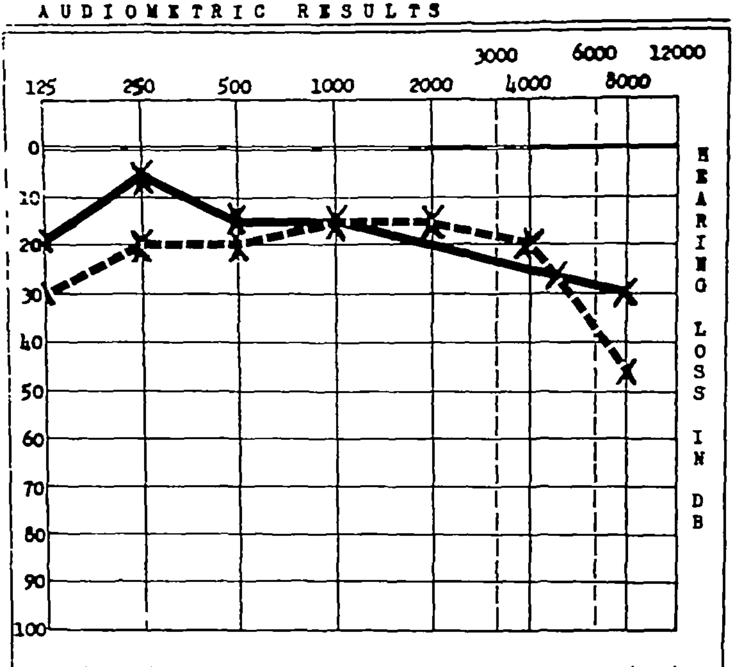

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June 18, 1957, an atticomastoidectomy was performed In the mastoid process a large confluent area of necrosis was found The entire periantral, perilabyrinthine areas and dural plate were necrotic and covered with granulations After dissection and removal of the disease the ossicular chain was found intact In September, 1957, the ear was dry with a remaining central perforation, the hearing was comparable to the preoperative findings the postoperative hearing loss in this ear averages 15 db (Audiogram, see Fig 8)

Case 9—D B, Male, age 10, first seen February 7, 1957, with a left acute subperiosteal mastoid abscess, temperature 101° F, and a discharging left ear, no landmarks could be seen because of the swelling His parents and the referring physician gave a history that one year prior to his present illness he had an acute ear infection treated with antibiotics which resolved without perforation or drainage

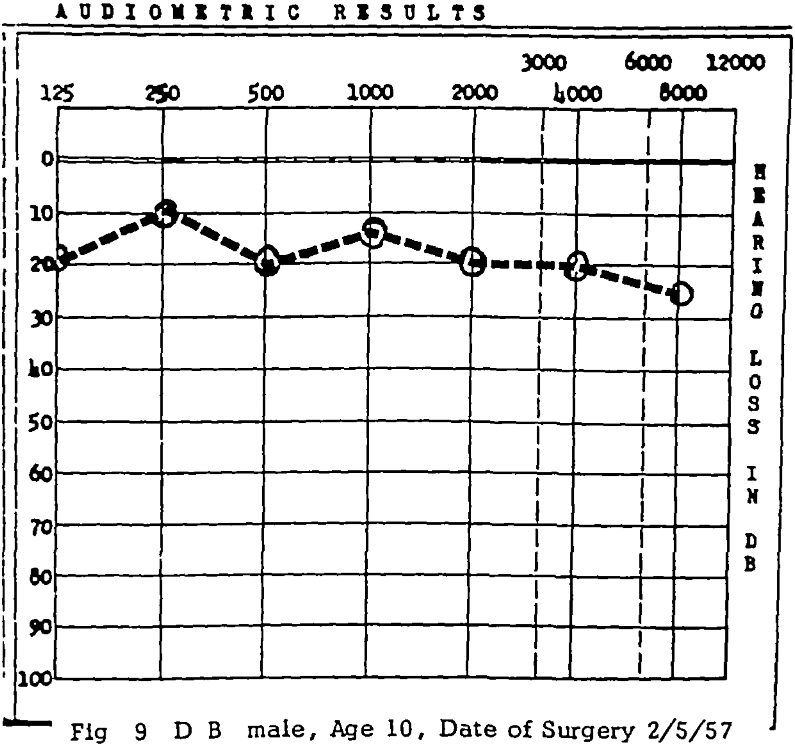


Fig 9 D B male, Age 10, Date of Surgery 2/5/57

There was no intervening difficulty until two weeks prior to admission when he developed pain in the left ear and a spontaneous discharge He was immediately placed on penicillin therapy and when this did not control the disease terramycin 750 mgms daily was added February 1, 1957 In spite of this treatment the patient developed a swelling over the left mastoid region on February 5 1957 while on the combined antibiotic therapy

X rays showed some clouding of the mastoid with some coalescence of the trabeculae

An atticomastoidectomy was performed on February 7 1957 There was extensive breaking down of the mastoid cells granulations covered the dural plate and a perisinus abscess was present, a cholesteatoma had eroded the lateral attic wall, the cholesteatoma matrix was completely removed under magnification, the intact ossicles and the remaining posterior superior canal wall were preserved a polyethylene drain was placed in the antrum and the incision was closed The ear was dry in one month, and at the present the previously unseen posterior superior perforation is healed and the hearing loss averaged 20 db on December 20, 1957

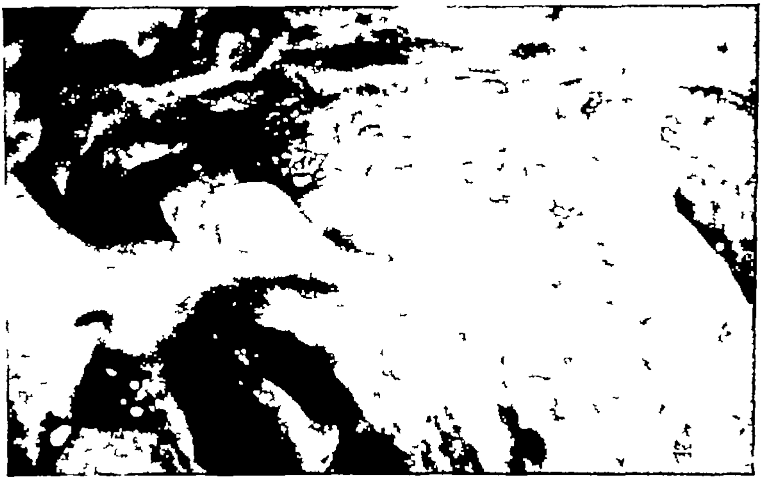


Fig 10 Photograph of surgery showing complete dissection of the anterior and the superior attic spaces and complete mastoidectomy The ossicles have been dissected free of all granulation

This case was included because along with Case V a small anterior attic cholesteatoma was found and removed through the atticotomy approach if a usual antrotomy had been performed the cholesteatoma would have been overlooked (Audiogram see Fig 9)

PATHOLOGY

Gross The usual findings are a dense cortex with patchy sclerosis in a previously pneumatized mastoid process There are isolated areas of trabecular necrosis along with osteogenetic thickening in other areas The areas most prone to bone necrosis are the perilabyrinthine cells and the dural plate, particularly in the area of the tegman antri, and attic

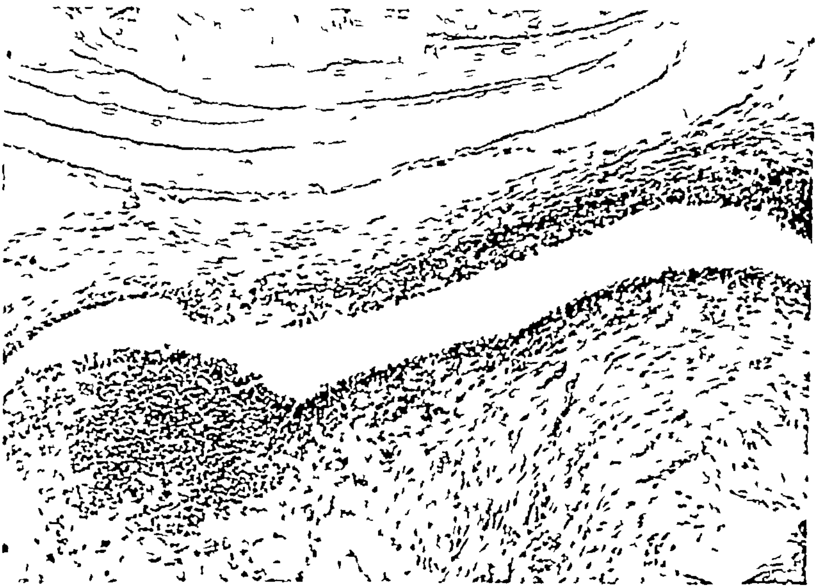


Fig 11 Microscopic view of bone removed from mastoid showing new lamella being laid down in an area of osteogenesis adjacent to fibrotic granulation tissue with round cell infiltration

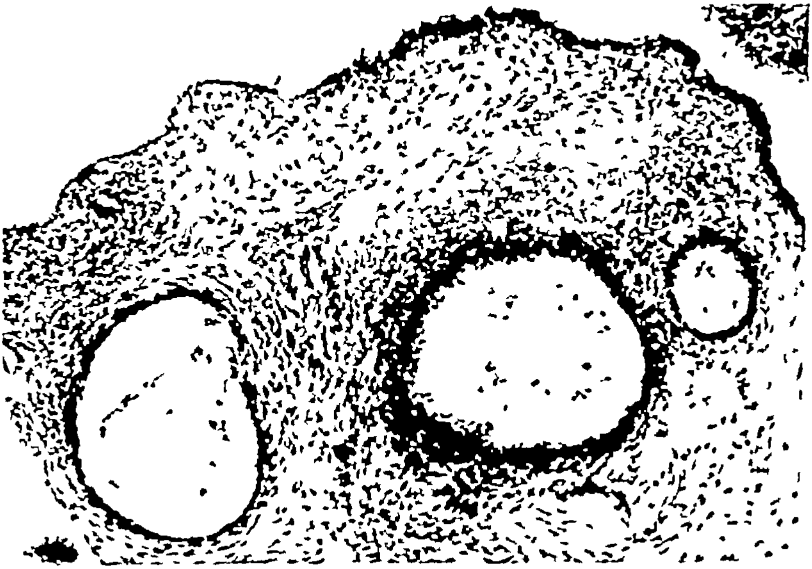


Fig 12 Microscopic view of cystic spaces in granulation tissue removed at mastoid surgery

Granulation tissue is present in the cellular remnants, in the antrum and about the ossicles Unsuspected cholesteatoma was found in two cases The ossicular chain is usually intact The bacteriology has been omitted, because it was noncontributory

Microscopic The chronic mastoiditis usually exhibits a hyperplastic mucosa with extensive round cells infiltration, plasma cells and edema The fibrosis is advanced in older cases Cystic spaces occur with cholesterine crystals Necrotic spicules of bone and empty lacunae with eroded cement lines are found in the more degenerative areas There are evidences of new bone formation with parallel darkly stained cement lines and osteoblasts (see Figs 11, 12)

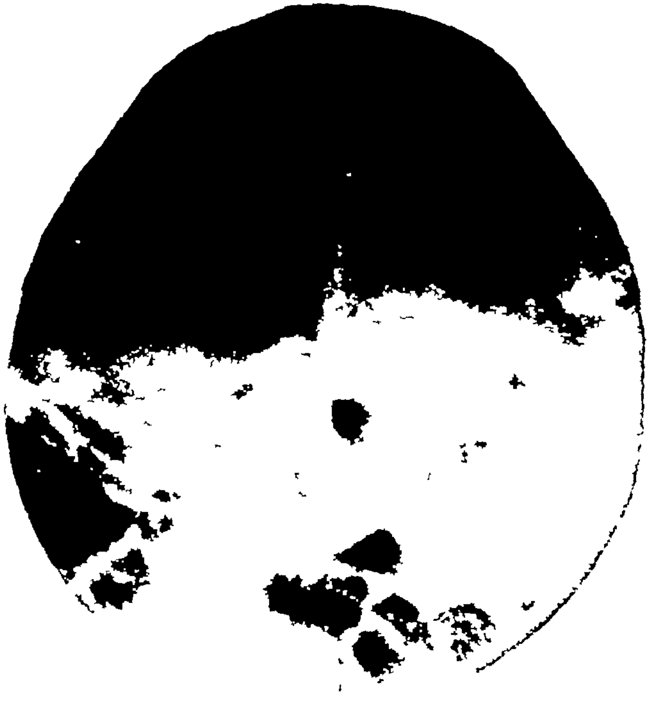
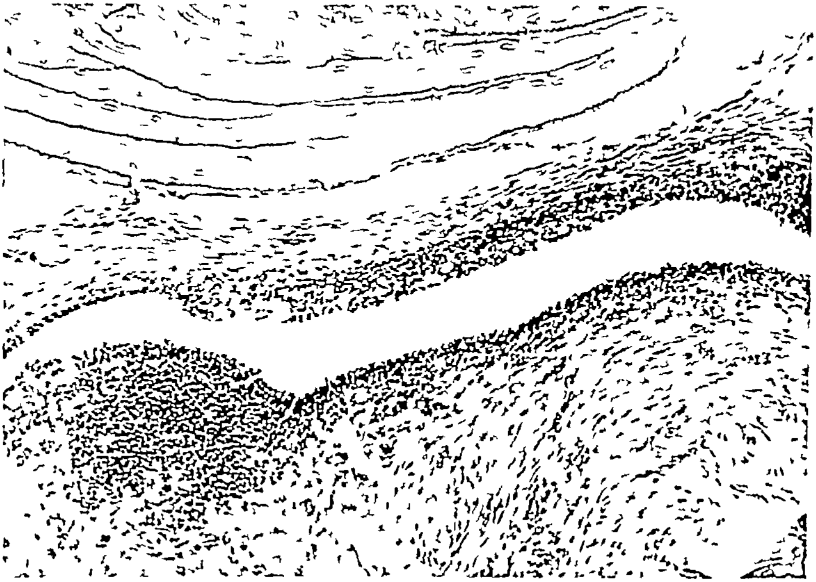


Fig 13 X-ray of extensive mastoiditis in previously pneumatized cavity with extensive sclerosis beginning



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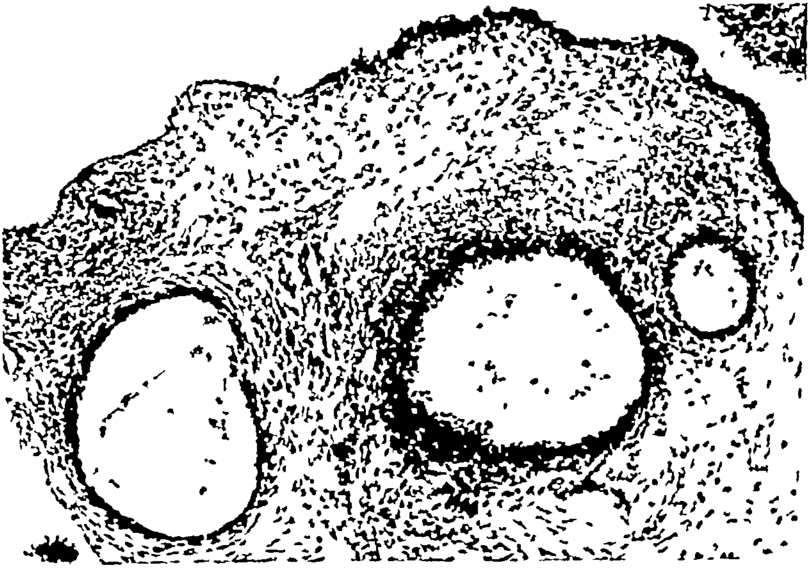

Fig 12 Microscopic view of cystic spaces in granulation tissue removed at mastoid surgery

of a previously pneumatized mastoid with small areas of necrosis, lack of aeration and extensive sclerosis as a part of the co-existing process of bone disease and osteogenetic repair This was confirmed by the pathology found at surgery It demonstrated the irreversibility of the disease, and often more extensive infection and destruction than had been expected was encountered This was particularly demonstrated in the attic along the dural plate and in the perilabyrinthine

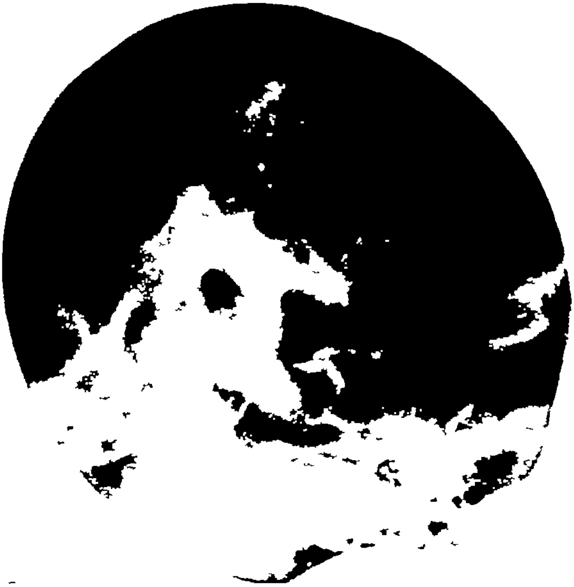

Fig 15 X-ray of a chronic mastoiditis showing extensive destruction and confluence of cells in the entire posterior aspects of the mastoid.

spaces by areas of bone necrosis, also unsuspected cholesteatoma was found in two cases Complete atticomastoidectomy without taking down the posterior or superior canal wall was performed All cases so treated resulted in a complete resolution of the temporal bone suppuration Most patients enjoyed a hearing improvement, often returning to the normal level of hearing Closure of the tympanic perforation often occurs spontaneously If the perforation is large it may be undertaken with tympanoplasty In most cases it

X-RAY

The mastoid was usually well developed on X-ray examination Sclerosis, loss of individual contours of cells and cloudiness of antral and periantral regions was observed, and larger peripheral cells, which may have been the result of confluence were common Their trabecular walls were markedly thickened Figs 13, 14 and 15 are typical X-ray views of mastoid pathology which could benefit from this type of surgery

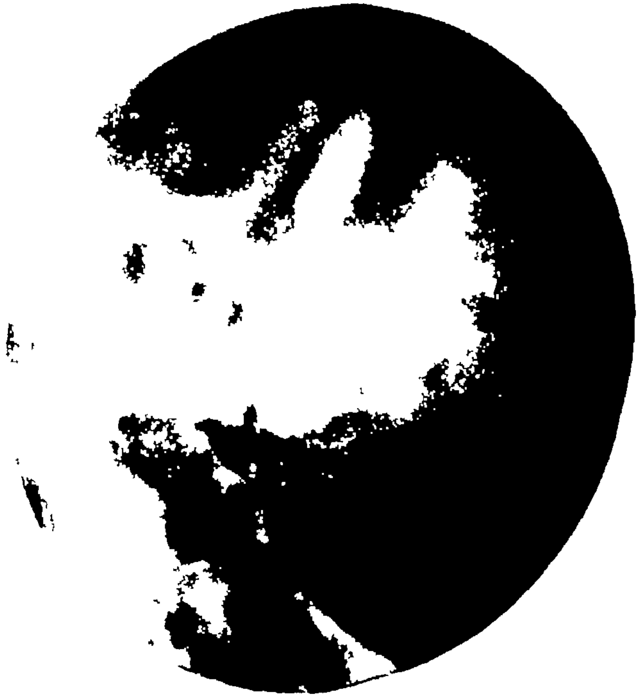

Fig 14 X-ray of a more contracted mastoiditis with a small area of destruction over the sinus

SUMMARY AND RESULTS

Nine cases of chronic suppurative otitis media, with central perforation, have been presented which did not respond to all current methods of nonsurgical therapy In these patients the X-ray picture of the mastoid usually gives the impression

STAPEDIO-VESTIBULAR OSTEOTOMY IN OTOSCLEROSIS

MICHEL PORTMANN, M.D.,
and
GILBERT CLAVERIE, M.D.,
Bordeaux, France

Stapes surgery has steadily improved since Rosen described his method for stapes mobilization in 1952. This operation is rational and fascinating, because it is essentially physiological. Despite this fact many otologists who have tried this surgery have been disappointed; in fact, the first reported statistics of the results showed only 40 per cent success. Several factors are responsible for the high incidence of failures obtained.

First, it is difficult to check thoroughly the extent of the pathology at the footplate of the stapes. It becomes even more difficult to perform the best surgical maneuvers suited for this particular type of footplate pathology. Manipulations often result in crural fractures rather than fractures in the articular interline itself. Occasionally the concomitant association of a complete closure of the round window by otosclerosis renders ineffective a successful stapes mobilization. In spite of these disadvantages many authors realize that the future of otosclerosis surgery lies in this type of operative approach, because it is rational and physiological.

Following "simple stapes mobilization" otologists began considering "stapes surgery," and even the concept of a "surgery of the labyrinthine window."[1] We mentioned in a previous report[1] the different procedures which we employ in the frame of this surgery according to the pathology encountered. We particularly emphasized the stapedo-vestibular osteotomy, which is the object of the present report. Its technical elements are as follows.

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has been our practice to delay closure of the drum by tympanoplasty because antibiotic dusting of the antral drain and middle ear is more efficient with an open drum membrane and also because postoperative closure can occur spontaneously, or be encouraged with trichloracetic acid cauterization We usually delay tympanoplastic closure until after the ear has demonstrated a prolonged period of healing and has not closed spontaneously

CONCLUSIONS

Atticomastoidectomy may be performed for chronic suppurative otitis media with central perforation of the tympanic membrane in appropriate cases with expectation of a cessation of discharge, resolution of the disease and restoration of normal or improved hearing

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SEVENTH INTERNATIONAL CONGRESS OF BRONCHOESOPHAGOLOGY

The Seventh International Congress of Bronchoesophagology will be held at Kyoto (Japan) University, September 12-14, 1958, under the direction of Prof Mituharu Goto, M D, Otorhinolaryngological Clinic, Kyoto University Hospital, Kyoto, Japan

A registration fee of $25 00 U S A will be charged all physicians and a fee of $10 00 for wives or non-medical guests Registered members are admitted free to banquet, receptions and sightseeing tours

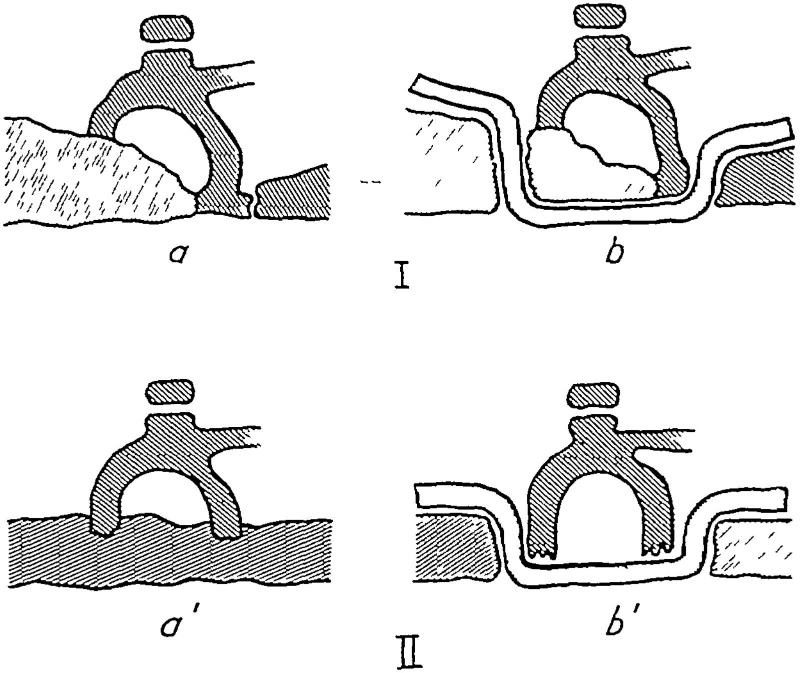

Fig 2 Principle of the Osteotomy with Interposed Graft.—I Osteotomy Type I—We can conserve the footplate a before the operation b after the operation
II Osteotomy Type II—We cannot conserve the footplate a. before the operation b after the operation

I APPROACH

The approach must be large so as to see the whole stapes with its footplate The operation includes either the retro- and supra-auricular approach which is large,[1] or the trans-meatal approach When we employ the latter the phases are as follows

First phase (Incision)

An incision is made one-half centimeter from the sulcus tympanicus from one to six o'clock on the left, or eleven to six o'clock on the right posterior canal wall

Second phase (Elevating)

The tympanomeatal flap thus formed is elevated and displaced anteriorly

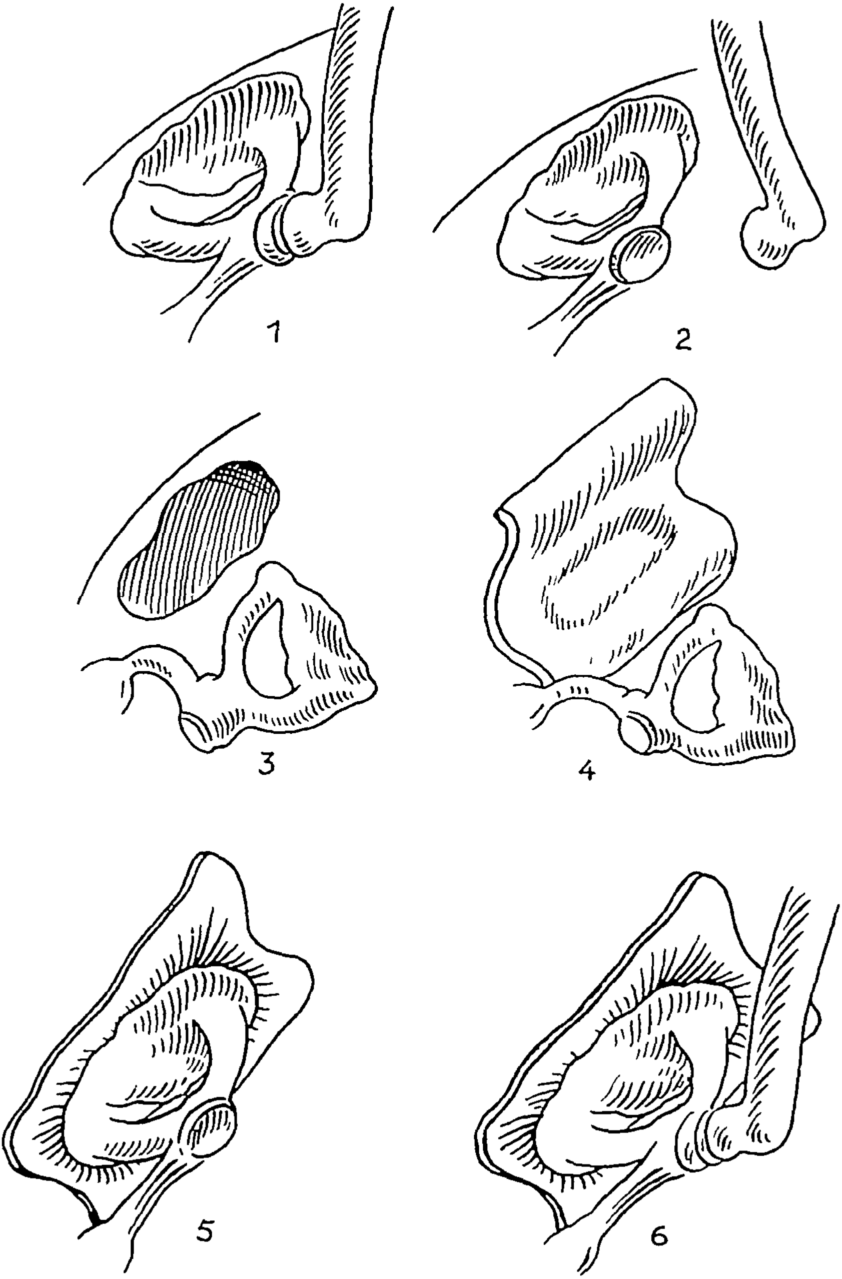

Fig 1 1—Stapes aspect before the operation 2—Disarticulation of the incus 3—Osteotomy and removal of the stapes 4—Graft on the oval window 5—The stapes is replaced in good position on the graft 6—The incus is replaced on the stapes head

Schematically the various essential aspects are

1 If it is beginning otosclerosis with a normal stapes and a visible articular interline a "simple mobilization" could be sufficient, however, it is always carried out by working on the footplate itself Direct action on the neck or head must be given up, or at any rate should be used only to finish a mobilization which has already been performed by maneuvers on the footplate

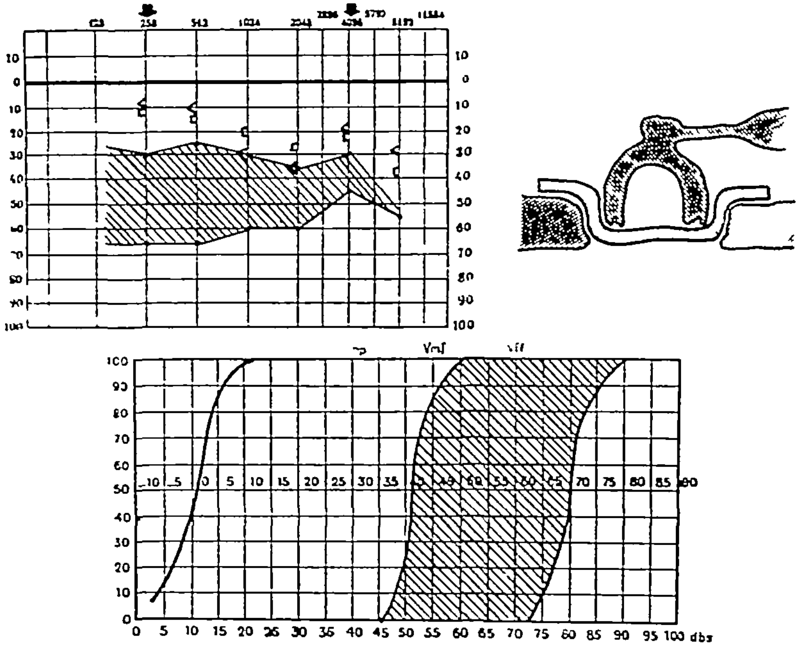

Fig 4 An Example of the Result Given by an Osteotomy—Type II. Shaded part the audiometric gain [bone conduction before the operation < bone conduction after the operation

2 If the osteome fills up a normal stapes because it presses against the crus, the osteotomy allows the removal of the part of the osteome which disturb the motion of the stapes

If the osteome has overgrown the anterior part of the articular interline, according to Fowler Jr, you can do a

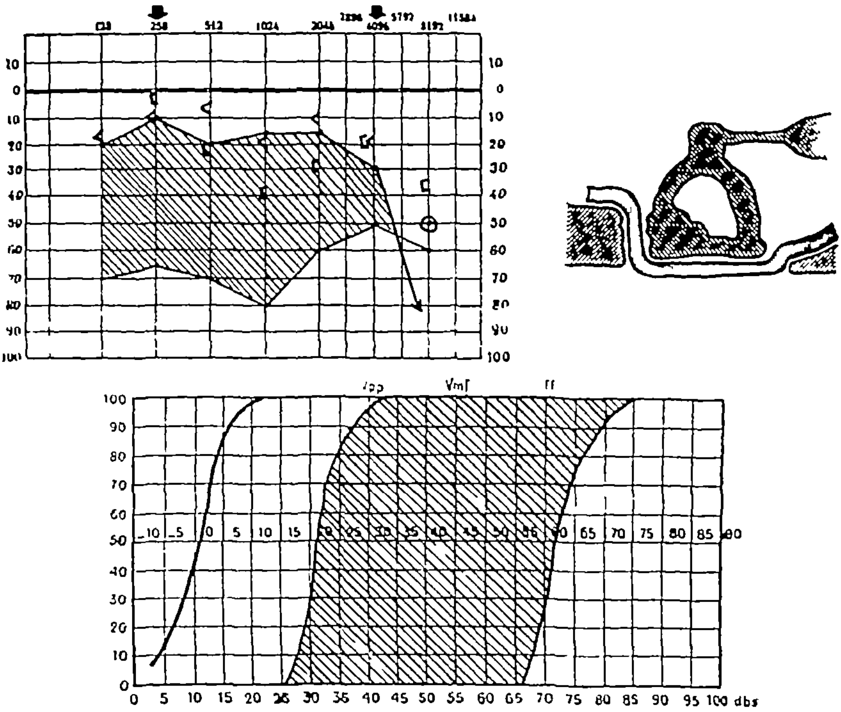

Fig 3 An Example of the Functional Result Obtained by Osteotomy—Type I. Shaded part the audiometric gain [bone conduction before < bone conduction after the operation A bone conduction gain is also noted

Third phase (Corda Tympani)

The corda tympani nerve is isolated and displaced anteriorly It can be cut if it is in the way

Fourth phase (Bone Resection)

Bony resection of the annulus is very important, in order to provide a good view of the whole stapes We prefer to use a burr with a bent hand-piece for this phase

Fifth phase (Disarticulation of the Incus)

The incus is detached at the level of the stapes head and pulled to the front It is replaced after the stapes phase

II PHASE OF STAPES SURGERY

The pathology on the periphery of the stapes is analyzed with 16 magnifications or higher

Technique of Osteotomy with Interposition.[3]

An objection could be made to the simple stapedo-vestibular osteotomy, in fact, the new interline obtained by the operation divides two pathological bony surfaces which are very active It is, therefore, logical to think that after a few years both parts of the osteome will unite again We tried to improve this osteotomy by the interposition of a tissue so as to prevent re-ankylosis The graft to be applied on the oval window must be very thin After various experiments we decided on the vein graft previously proposed by Shea, Jr, that is, a small section from a vein of the back of the hand cut open along its long axis The connective tissue is thinned down This graft constitutes an excellent material to apply on an oval window

Type I As soon as the osteotomy is performed the stapes is removed from its frame so that the oval window is open, however, the ossicle keeps one connection with the walls of the tympanum by its muscle tendon which is not cut off It is turned over its tendon and pulled down so that it does not impede work on the oval window itself The mucosa which surrounds the window is removed The graft is then applied to the window with its adventicia toward the labyrinth and its endothelium toward the tympanum Finally the stapes is replaced into its proper place in the window, but on the graft which is used as an interposition

Type II In certain cases the window is completely closed by a very thick and white bone from which the crura seem to emerge It is not possible to create a footplate in such a lesion We must then cut the crura near the osteome so that the stapes consists of only the head and crura It is still attached to the stapedius tendon The oval window is then cleared of otosclerotic bone The graft is applied, endothelial side out, to the recreated oval window The stapes is then replaced with the ends of the crura directly connected with the vein graft, which is used as a footplate

III CLOSURE OF THE OPERATIVE FIELD

Bleeding must be avoided After suction the necessary section of the anterior crus and the anterior part of the footplate to isolate the lesion One can also make an osteotomy

3 In many other cases the osteome is more extensive and occludes the articular line We can then perform a stapedovestibular osteotomy

4 Sometimes the lesion covers the entire stapes completely In this case it is again possible to try an osteotomy and a "fenestration" in the area of the oval window

We have then several methods of stapedio-vestibular osteotomy available according to the type of pathology

Instruments

We employ the following instruments

Thin osteotomes needles and fine hooks with a straight handle and also with a spoon-shaped handle The shape of the latter (after the Zollner idea) facilitates visibility but does not permit the rotary motion, which is possible only with a straight handle instrument

A special microdrill, already described[2]

Thin suction tubes permitting the washing with serum This liquid with a composition similar to perilymph should be used at 37° centigrade

Technique of the Simple Osteotomy

With the thin osteotomes (needles) small holes are made in the expected zone of the articular interline We must be careful not to crack the crura When this maneuver is impossible, due to the thickness of the bone, we must have recourse to the microdrill This permits the performing of microscopic labyrinthine trepanations like a dotted line crossing the lesion It is then possible to fracture the bone between the holes and thus obtain mobilization In some cases the pathology is very localized, generally in both the upper and anterior part, so that the osteotomy must be performed only in this area Occasionally the footplate is atrophic, transparent and contrasts with the density of the anterior part Then the action must be very gentle in order to avoid its fracture

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III CLOSURE OF THE OPERATIVE FIELD

Bleeding must be avoided After suction the necessary microcoagulation is performed The incus is put back in place on the head of the stapes The corda tympani nerve is replaced and finally the tympanomeatal flap

Post-operatively the patient may present a syndrome of labyrinthine irritation, sometimes severe, with nystagmus toward the side of the operation The slightest motion of the head may provoke dizziness and nausea This reaction disappears within a few days Sometimes there is no reaction at all

CONCLUSION

These surgical procedures are still in the experimental stage The excellent results which we have obtained with them indicate that they are an improvement in stapes surgery The percentage of success for all stapes surgery is steadily increasing despite many persistent technical difficulties and as yet unestimated surgical risks We believe that future technical progress will result in maximum results

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AMERICAN BOARD OF OTOLARYNGOLOGY

The American Board of Otolaryngology will conduct only one examination in 1958, and this will be October 6-9, 1958, in Chicago, Illinois, at the Palmer House

For further information address Dr Dean M Lierle, Secy-Treas, University Hospital, Iowa City, Iowa

UNILATERAL PARALYSIS OF VOCAL CORD FOLLOWING ADMINISTRATION OF TETANUS ANTITOXIN (TAT) *

MILOS BASEK, M D ,

New York, N Y

Any peripheral neuritis after administration of tetanus antitoxin (TAT) is very rare, if one considers the enormous number of persons treated with it Involvement of the recurrent laryngeal nerve is even less frequent, but nevertheless it should be known that it may occur Bearing this in mind may be helpful in establishing the correct diagnosis of unilateral vocal cord paralysis of "unknown" origin The prognosis is uniformly good and no specific treatment needed Incidentally ACTH and Cortisone have been tried without any significant acceleration of recovery

The etiology and pathology of this entity were well discussed in previous papers,[1,4,10,11,12] and the reader is referred there for details Involvement of the recurrent laryngeal nerve probably follows the same pattern as in other peripheral nerves, *i e* edema of the nerve due to impaired blood supply, which causes temporary damage to the nerve and impairs its function The damage to other peripheral nerves, especially those of brachial plexus, may be permanent, and certain authors assess the incidence as high as 20 per cent[4,12] In both of our cases, in spite of good and relatively fast functional recovery, there remained some sluggishness in movements of both vocal cords and arytenoids even six months after the onset of the paralysis One year later, however, both cases showed normal function

It is generally stated that neuritic complications after TAT appear about one week after its application[4] This was true in our second patient, who had a paralysis of the left vocal

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*From the Department of Otolaryngology Columbia University College of Physicians and Surgeons and the Presbyterian Hospital in the City of New York

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cord as a single complication after TAT administration The first patient, a case of severe tetanus infection, had a right brachial plexus involvement with paralysis of right vocal cord which was discovered in the fourth week of hospitalization Here, however, TAT was given both prophylactically and later on, therapeutically, in high doses, so that it was hard to decide which one of these separate doses of TAT was the cause of paralysis

REPORT OF TWO CASES

Case 1 P R, 18 years old white male admitted on September 2 1952, with chief complaint of stiffness of neck and pain in throat and shoulders of 16 hours duration One week prior to the admission the patient fell down cutting his right forearm on a dirty rock The wound was sutured by a local physician, a prophylactic dose of TAT was given and the patient started on penicillin twice a day Two days prior to the admission the wound became infected and several sutures were removed by the local physician The following day the patient began to feel stiffness in his neck and throat and was running temperature On admission there was stiffness of neck pain on motion of neck shoulders and upper back muscles Trismus was pronounced, making the examination of the larynx impossible There was, however, no hoarseness and no respiratory distress Laceration 6 cm long on the right lower forearm was infected and partially closed with three sutures The wound was opened, cultures and smears taken which eventually grew Clostridium tetani debridement and treatment with irrigations and soaks were carried out Patient received 200,000 units of TAT 60 000 of which were injected around the wound and 140 000 i m In spite of heavy sedation he had frequent attacks of opisthotonic spasms and required tracheotomy on the second day for laryngospasm After a severe and rather stormy course he improved after three weeks, and tracheotomy tube was removed on the twenty first postoperative day Toward the end of the fourth week of hospitalization it was discovered that he was hoarse, and indirect laryngoscopy showed a paralyzed right vocal cord At the same time he developed weakness of right shoulder, forearm and wrist He was improving quickly without any specific therapy, and three months later his voice was normal and only some sluggishness of the movements of the right cord and right arytenoid still persisted Last check on April 29, 1954, showed a perfectly normal function of both cords

Case 2 F L 43 years old, white male was seen at E N T Clinic on June 9 1953 with a chief complaint of hoarseness of seven weeks' duration Indirect laryngoscopy revealed a paralysis of left vocal cord with minimal movements of left arytenoid His history was essentially negative except that he was given 'a tetanus shot" by his local physician for puncture wound of his foot One week following the injection he suddenly became dyspneic and hoarse Dyspnea disappeared soon, but hoarseness persisted Patient was referred to Speech Clinic for speech therapy and improved very much in one month When seen at E N T Clinic one year later his left vocal cord showed normal function

SUMMARY AND CONCLUSIONS

Two cases of paralysis of the recurrent laryngeal nerve are reported where the cause apparently was the reaction to TAT The first case developed unilateral paralysis of the vocal cord after therapeutical dose of 200,000 units of TAT after having received a prophylactic dose one week before therapy was started In this case there was an associated involvement of right brachial plexus The second case developed unilateral paralysis after prophylactic dose of TAT, and this was the only complication present

Both cases improved functionally *ad integrum* within six months without any specific therapy The second case received speech therapy, which we believe was helpful to overcome faster the acute period of voice impairment and helped him in social readjustment

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DIFFERENCE LIMEN OF INTENSITY IN HEARING IMPAIRMENT DUE TO CRANIOCEREBRAL INJURY *

Armo L Hormia,

Turku, Finland

Auditory damage in connection with craniocerebral injury is due to labyrinth concussion, which damages the organ of Corti This has been confirmed by both experimental studies (Schuknecht[20]) and by clinical observations (Drooker,[6] Grove[9]) According to the severity of the blow, the end-organ damage consists of loss of the external hair cells, loss of the external and internal hair cells, or complete disappearance of the organ of Corti (Schuknecht[20])

In Ménière's disease, recruitment is a constant finding This is also the case in end-organ deafness caused by acoustic trauma In retrolabyrinthine hearing disorders, on the other hand, recruitment does not exist (Day,[4] Dix,[5] Eby and Williams,[7] Reger and Kos[18]) Even though the difference limen and recruitment phenomena are not exactly identical, they are, however, based on related physiological backgrounds (Fowler,[8] Hirsh,[10] Lund-Iversen,[14] Tonndorf[21]), therefore, in cases with recruitment, a reduced difference limen for intensity has been observed and vice versa (Békésy,[1] Lundborg,[13] Luscher,[16] Jerger[12])

As the hearing loss following head injury, is due to end-organ damage, one might suppose that the recruitment phenomenon and a reduced difference limen should be characteristic for it, however, clinical observations show that patients with concussion of the labyrinth after severe head trauma do not respond uniformly Both cases with decreased difference limen and recruitment, as well as cases with normal difference limen and without recruitment have been seen (Luscher,[16] Saltzman[19])

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*From the Brain Injury Hospital Helsinki Eero Hillbom M D Chief

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MATERIAL

The difference limen in hearing impairment due to craniocerebral trauma was investigated by means of Bekesy[1] audiograms in a series of 43 war veterans In this series were included all cases with a hearing loss of at least 30 db in one or more frequency ranges The age of the patients varied from 30 to 50 years, being 37 years on an average The investigation was carried out on an average of 12 years after injury In every case a detailed neurologic investigation was undertaken, and in a detailed psychologic investigation, special attention was given to signs of impaired perception and attention capacities In each case, the subjective troubles caused by the hearing impairment were also noted In the symptomatology, the symptoms of cerebral injury dominated, the hearing impairment being of secondary importance In 30 cases the primary injury had been a local cranial trauma due to high-speed missiles, generally shrapnel and bullets In the other 13 cases the primary injury had been a craniocerebral concussion

In analogy with Lundborg,[13] the Bekésy[1] audiograms were grouped in four types according to the amplitude of the difference limen Type IV represents a strongly reduced difference limen, Type III a partially reduced one, Type II, a tendency to a reduced difference limen, and Type I, a normal difference limen In addition to this, patients with a difference limen higher than 20 db at some frequency ranges formed an extra group of a high difference limen (Luscher[16])

RESULTS

In one single case the Bekésy[1] audiogram represented Type IV This was a case of temporal injury The hearing was impaired, and the reduced difference limen was present in the ear opposite the site of injury This finding is not at all in accordance with the pattern of hearing impairment seen in temporal injuries (Hormia[11]) Indeed, in the light of other clinical findings, this case could be diagnosed as morbus Ménière, independent of the trauma

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In four cases the Békésy[1] audiograms represented the Type III, and all belonged to the group of local injuries

In eight cases the Békésy[1] audiograms represented Type II From these, five were local injuries and three concussions

In nine cases, the Békésy[1] audiograms represented Type I, with a normal difference limen Of these, three were local (right temporal) injuries, and six were concussions

In 23 cases the difference limen was higher than normal From these, 19 were local injuries (with a total of seven parietal) and four were concussions In two cases the difference limen decreased somewhat in higher frequency ranges (These cases are, therefore, included also in the group of Type II) The highest average difference limens seen in this series were 30-35 db

TABLE I

The correlations between the amplitude of difference limen in Békésy audiogram and the hemisphere of the craniocerebral injury the effectiveness of perception and attention capacities, and the subjective inconvenience of the hearing impairment

	Hemisphere of the Head Injury		Perception and Attention		Hearing Impairment Subjectively	
	left	right	impaired	others	not disturb	disturb
Cases with High Difference Limen	15	8	10	13	17	6
Other Cases	8	12	5	15	9	11

Checking the factors which could be significant of a high difference limen, it was seen that in these cases the following factors were more common than in the other cases (see Table I)

The primary injury was located on the side of left hemisphere

As a consequence of the brain injury, the perception and attention capacities were greatly deteriorated

The hearing impairment was subjectively not disturbing for the patient

Regarding no one of these factors could the results be shown to be statistically significant because of the small number of cases The significance of these three factors may be seen more clearly by examining their total effect From the 23 cases with a high difference limen eight had less than two of the three factors mentioned above, in 15 cases two or three of the factors were present In the series of the other 20 cases the numbers were 15 and five This shows a clear difference between the group of cases with a high difference limen and the other group (Statistically significant, $\frac{X}{\sigma}=2\ 62$)

DISCUSSION

In the light of the material presented above, it is obvious that a reduced difference limen is not characteristic for the hearing impairment in connection with craniocerebral injuries, yet the mechanism of the hearing impairment is one of labyrinth concussion and it thus is a question of end-organ deafness This result does not agree with the prevailing opinion that a reduced difference limen and recruitment are typical of labyrinth deafness

Some investigators have explained the recruitment phenomenon as due to reaction of the more intact inner hair cells in cases with damaged outer hair cells (Lurie,[15] Meyer zum Gottesberg[17]) The inner hair cells lie directly against the bone, thus, it is reasonable to assume that in cases with severe head injury the concussion effect which reaches the labyrinth through the bones of the skull also damages the inner hair cells There can even be a secondary degeneration of the peripheral cochlear neuron (Schuknecht[20]) Compared with the mechanism of acoustic trauma (Bernabei[2]) and the increased endolymphatic pressure mechanism of the hearing impairment in Menière's disease (Cawthorne and Hewlett[3]), it seems possible that in cases of blows to the head the inner hair cells receive relatively more damage, even though these are not so easily injured as the more sensitive outer hair cells

The explanation of the absence of reduced difference limen in cases with deafness due to head trauma may be found in a more uniform damage of the organ of Corti with its nerve supply

A high difference limen was seen in one-half of the cases Luscher[16] has expressed the significance of psychic factors for the occurrence of high difference limen This observation was confirmed in the material presented above High difference limen was seen especially in cases where the cerebral injury was on the side of the dominating hemisphere and had caused a deterioration of the perception and attention capacities It was also seen that the subjective inconveniences of the hearing impairment for these patients were of less degree than for the others This can be understood as a sign of a deterioration, especially of those areas of perception and attention functions which are closely connected with auditive sensations (Hormia[11]) These findings show that the psychic factors causing high difference limen can be due to organic brain damage

SUMMARY

The difference limen in hearing impairment caused by craniocerebral injury was studied with the Bekesy audiograms in a series of 43 war veterans In only four cases could a partly reduced difference limen be seen As a possible explanation for the absence of reduced difference limen, the mechanism of the hearing impairment in connection with head blows was considered It is a question of end-organ deafness due to concussion of the labyrinth This concussion wave reaches the labyrinth through the bones, therefore, the inner hair cells are more prone to the damage and a more uniform damage of the organ of Corti results than in those types of end-organ deafness characterized by a reduced difference limen and presence of recruitment

A high difference limen was seen in one-half of the cases In these cases signs of deteriorated (auditive) perception and attention capacities were noted The result thus confirms the significance of psychic factors upon the incidence of a high difference limen

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BASIC TECHNIQUES IN MYRINGOPLASTY AND TYMPANOPLASTY *

FRED R GUILFORD, M D ,
and
WM K WRIGHT, M D ,
Houston, Tex

The work of Wullstein[1] and Zollner[2] in the practical application of the technique of tympanoplasty has stimulated otologists throughout the world to become interested in this phase of rehabilitative surgery Berthold in 1878, first closed a perforated ear drum successfully and reported several successful results Eli,[4] Tageman[5] and Roosa,[6] in America, tried the operation with questionable results There was a definite cessation in the practice of tympanoplasty from 1900, until the reports of Wullstein and Zollner again focused attention on the procedure Since then thorough studies and results were reported, it is a matter of history that the technique has been adopted enthusiastically, and modified to some extent by otologic surgeons everywhere[7-9]

We consider[10] tympanic skin grafting to be the basic technique, and the five types of tympanoplasty to be modifications of this technique These modifications depend upon the pathology found in the sound conduction mechanism, the ossicular chain, oval window and round window, as well as upon the pathology in the mastoid cavity In all types, control of suppuration in the middle ear and mastoid, as well as main-

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*Read at the meeting of the Southern Section American Laryngological Rhinological and Otological Society Inc Memphis Tenn Jan 25 1958

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tenance of an air space connecting the two mobile functioning windows to an adequately functioning Eustachian tube, is necessary. The middle ear must be lined with mucous membrane, and the cochlear reserve should be adequate for complete success of the procedure.

PREOPERATIVE PROCEDURES

I.—*Control of Suppuration*

Culture and sensitivity tests are obtained, and the patient is started on specific local and systemic antibiotics when available. Burrow's solution, gentian violet or 25 per cent argyrol solutions are used locally when the tests reveal the organism insensitive to specific antibiotics. To obtain better contact between drug and organism the secretions in the middle ear are aspirated at intervals of 48 to 72 hours, and the drug administered through a cannula directly into the involved area of the middle ear. This is done in addition to local administration of the drug several times daily by the patient. If a focus in the mastoid fails to resolve, a thorough simple mastoidectomy may be done. Except when cholesteatoma is present, these methods usually produce a dry ear. If radical mastoid surgery should be necessary, it should be as conservative as possible, especially with regard to saving the annulus, mucous membrane of the middle ear and Eustachian tube function. There is little to be gained from sacrificing these structures, and they are vital in surgical reconstruction of the middle ear and sound conduction mechanism by tympanoplastic techniques.

In order to create a patent Eustachian tube and prevent recurrent infection, an adenoidectomy and sinus, or allergic treatment, may be necessary.

II.—*Test the Eustachian Tube Function*

Careful examination of the ear may rule out middle ear effusion and retraction pockets, and determine whether a middle ear air space is present. Politzerization, Valsalva maneuvers and catheterization and inflation of the Eustachian tube will be helpful. These procedures give valuable information, but at present we do not have an absolute test of Eustachian tube function

III—Search for Presence of Cholesteatoma

A meticulous examination is made for marginal perforations, squamous epithelium in the middle ear, or cholesteatomatous debris in the perforation Magnification with the Zeiss operating microscope will be helpful in this study Mastoid X-rays may be useful If in doubt, exploration of the mastoid, epitympanic area and middle ear is done at time of surgery before skin grafting procedures are attempted

IV—Testing of Hearing Function

1 Air conduction, bone conduction, speech reception threshold and discrimination tests are done routinely

2 Patch test—when possible a paper patch is applied to the tympanic perforation to close the opening temporarily, and an air conduction test is made with the patch in place When the patch can be applied successfully and a complete seal occurs in all areas around the periphery of the perforation, valuable information concerning the integrity and function of the ossicular chain may be obtained If closing the perforation with a paper patch increases hearing appreciably, the ossicular chain is presumably intact

3 Acoustic Probe—In those cases when it is not possible to apply a patch successfully because of the size of the defect in the drum, the acoustic probe is used to determine the efficiency of the ossicular chain In the presence of cholesteatoma the acoustic probe test results may not be reliable, because it is possible for the cholesteatomatous mass to act as a conducting mechanism between the parts of a disrupted chain The results may indicate that the chain is intact and functioning, but an obvious defect in the chain may be apparent following removal of the cholesteatoma, especially in the area of the incus

TECHNIQUE OF MYRINGOPLASTY

Special Problems Associated with Tympanic Skin Grafting The successful take of the graft while bridging an air-containing cavity (the middle ear), is an important problem in this type of skin grafting The bed for this graft lies peripherally, formed by denuding the tympanic remnant, the annulus, and often the adjacent canal wall, of squamous epithelium These skin grafts differ from the usual skin graft in that their central portion, which overlies the defect, is not in direct contact with any blood supply

Most authorities agree that the permanent blood supply of a graft occurs when endothelial vascular buds grow from the bed blood vessels out into the graft and make continuity with the graft blood vessels between the fourth to tenth postoperative day Paget[11] and Conway[12] feel that most skin grafts survive the first few days on a plasmic circulation diffusing extra-cellularly from the bed blood vessels up into the graft We have previously reported our belief that this type of circulation could nourish only that portion of the graft which lies directly adjacent to the bed, and we believe that some primitive type of intravascular circulation nourishes the central portion of the graft soon after its application to the bed We believe that an intravascular circulation begins within 24 hours through the matching of the many severed ends of the capillaries in the graft with the numerous capillary endings in the denuded vascular bed Thus an early intravascular circulation occurs through the parallel subepithelial vascular network into all portions of the graft A tympanic skin graft must be cut thick enough to include the network of blood vessels running parallel to the skin surface

In general, there are two such networks a superficial one running just below the dermal papillae, and a deep one lying in the middle of the dermis These vascular networks have rich anastomoses A thin split thickness graft may contain none of this parallel blood supply, and the central portion of the graft would probably slough The full thickness graft and the three-fourths thickness split graft contain both the superficial and deep vascular networks and are better suited for tympanic skin grafting We prefer the three-fourths thickness skin graft, as it is not necessary to clean the fat from the under surface of the graft, and possible trauma to the graft's blood vessels is avoided

Only gentle pressure should be used in packing the graft in place Pressure of greater than 10 cm of water may collapse the capillaries in the graft and cause a slough of the central portion of the graft

We have previously reported other factors which we believe are important in successful tympanic skin grafting

I Absence of Infection To guard against latent infection, surgery should be postponed until the ear has been perfectly dry for at least 30 days We recommend pre- and postoperative antibiotics, sterile surgical preparation, sterile operating room technique and sterile postoperative care in office dressings A two-stage operation may be necessary, with the first eradicating the infection, and the second repairing the middle ear defect after the infection is completely controlled

II Good Exposure of the Entire Tympanic Remnant and Annulus This is a vital factor in the success of the procedure done through the transmeatal route and can be an important factor in the conventional endaural approach as well Occasionally the transmeatal procedure can be done through the intact ear canal, but a modified endaural and anterior U-shaped incision is usually required, and enlargement of the bony canal may be necessary

The bed must be completely denuded of every vestige of squamous epithelium, and the graft must be placed in close apposition to the bed with an adequate overlap Binocular magnified vision of all surfaces is required, and the anterior sulcus formed by the tympanic remnant and the anterior canal wall at the annulus is the most difficult to visualize properly In the transmeatal approach, it should be remembered that the visibility is never so good as it appears to be at the beginning of the operation

III Atraumatic Preparation of the Vascular Bed and Handling of the Skin Graft The graft and the bed should be prepared with only the sharpest instruments They should not be allowed to dry, and the graft should not be washed in normal saline or other so-called physiologic solutions, which may be injurious to the graft Crushing of the graft with scissors or forceps should be avoided

IV Regrafting If the primary graft fails because of slough, it is well to regraft as soon as the failure is discovered The first graft invariably stimulates the vascularity of the bed, and the second graft is more likely to succeed than the first if repeated within the first three or four months

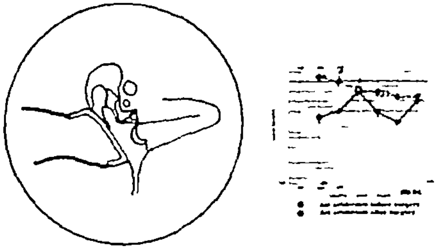
TECHNIQUE OF MYRINGOPLASTY

Type I—Tympanoplasty Anesthesia is obtained by injection of 2 per cent xylocaine with 1 50,000 adrenalin in the postauricular sulcus and mastoid area At the osteocartilaginous junction in the canal, and along the roof of the canal, 1 5000 adrenalin is used in the xylocaine for hemostasis In some individuals supplementary general anesthesia in the form of intravenous pentothal is advisable (see Fig 1)

MODIFICATIONS OF TYMPANIC SKIN GRAFTING

TYPE I

Pathology Simple perforated tympanic membrane with intact ossicular chain
Rx Skin graft closure of the perforation will result in essentially normal hearing



Mrs AC—Age 29 Large 6 x 6 mm. dry central perforation present for 10 years Patch and acoustic probe revealed an intact ossicular chain. Mastoid x rays negative
Rx: Type 1 Tympanoplasty

Fig 1

A modified endaural incision is made (see Fig 2) and the first incision is carried along the roof of the canal to a point 2 mm from the drum A second incision is then made across the posterior wall of the canal parallel, and 2 to 3 mm lateral to the annulus It extends as far as the junction of the floor of the canal with the posterior wall A third incision is then

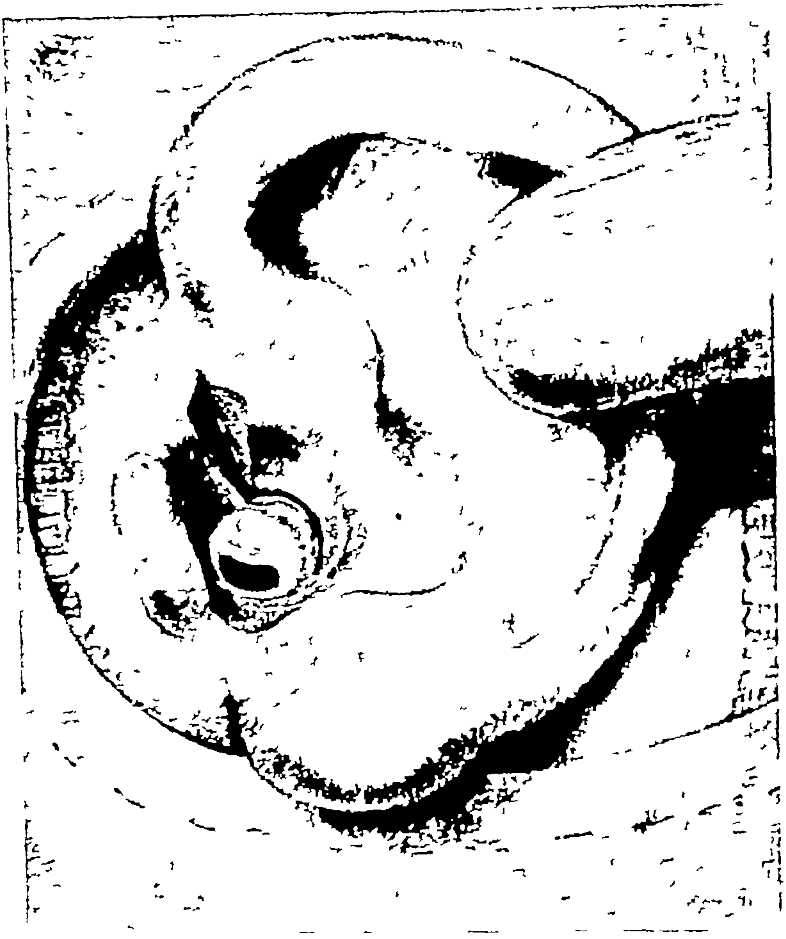


FIG 2

made from the inferior end of the second incision laterally to the osteo-cartilaginous junction The skin flap outlined on the posterior canal wall by these incisions is then elevated laterally After partial elevation of the periosteum over the mastoid process, the posterior canal flap is tucked between the overlying soft tissue and the mastoid process, to be replaced in the canal at the end of the operation A self-retaining retractor is inserted, leaving both hands free for instrumentation A U-shaped flap is now cut from the skin of the anterior canal wall (see Figs 3, 4) The lower portion of the U extends across the canal parallel to, and approximately 3 mm lateral to the annulus The vertical portion of the U falls into the junction of the roof of the canal with the anterior wall and the junction of the floor with the anterior wall respectively The vertical incisions extend to the osteo-cartilaginous junction on

Fig 3

the anterior wall The anterior flap is then elevated and rolled up onto the skin of the anterior cartilaginous level, to be replaced at the end of the operation The overhanging bone of the anterior canal wall is thinned with a sharp mastoid curette until the anterior sulcus can be well visualized

The graft bed is prepared by removing the outer layer of squamous epithelium from the rim of the drum and adjacent canal wall with specially made tympanic membrane curettes Occasionally a sharp knife is used to trim the cuff from the inside of the perforation which is formed by the junction of the squamous epithelium with the mucous membrane from the undersurface of the drum After denuding the fibrous layer,

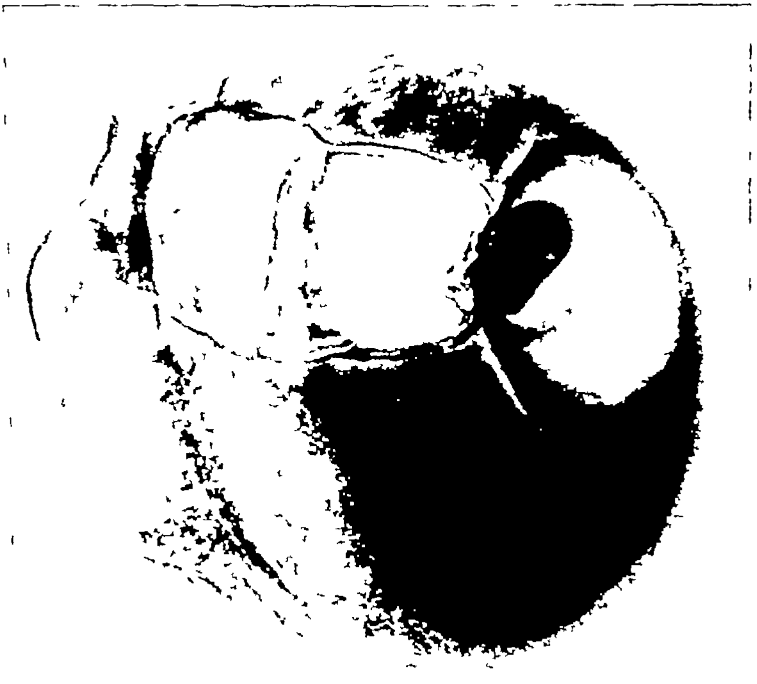
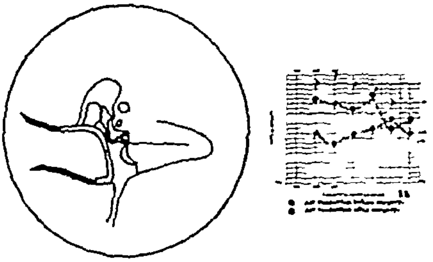


Fig 4

the perforation is measured with a fenestrometer An appropriately sized three-fourths split thickness graft is then cut with a "Weck" razor blade from the non-hair bearing skin over the mastoid The graft is placed raw surface up on a tongue blade and cut to measure with a scalpel, so that it overlaps the perforation 2 to 4 mm in all directions save posteriorly, where it overlaps 4 to 6 mm The graft is placed in position on the tympanic remnant, and all edges are everted with sharp picks It is then pushed into contact with the drum and anterior sulcus with a wire ring curette The graft is then covered with small strips of cigarette paper, and one-sixteenth-inch cotton balls are gently placed against the annulus and over the central portion of the graft The anterior and posterior skin flaps are now rolled back into place, covered with cigarette paper strips, and the remainder of the canal filled with antibiotic ointment impregnated cotton balls The incision along the roof is protected by a strip of surgical rayon, and the small external incision is closed with silk The donor site is covered with antibiotic ointment impregnated rayon and a mastoid dressing is applied

TYPE IIA

Pathology	Perforated tympanic membrane with erosion of malleus
Rx	The graft is placed so that it contacts the incus



Mr RB Age 16 Draining ear since childhood Examination revealed a 5 x 7 central perforation with erosion of the handle of th malleus
Rx. Infection cleared with local specific antibiotics Tympanic skin graft used to close perforation and placed in contact with th incus

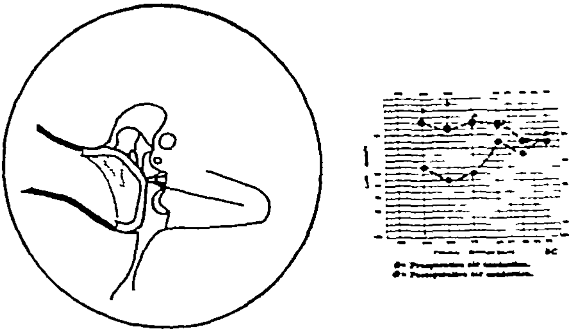
Fig 6

The patient is maintained on an appropriate antibiotic for 24 hours preoperatively, and seven days postoperatively The packs are removed on the seventh day, and the cigarette papers wiped out on the 14th day The mastoid dressing is removed after 48 hours and a small dressing applied over the rayon on the donor site, which is usually healed in 10 days

MODIFICATIONS OF TYMPANIC SKIN GRAFTING

The Type I technique has been described We have divided the Wullstein Type II into A and B classifications (see Fig 5)

Type II-A Pathology—a perforated tympanic membrane with erosion of the long process of the malleus and an otherwise intact ossicular chain



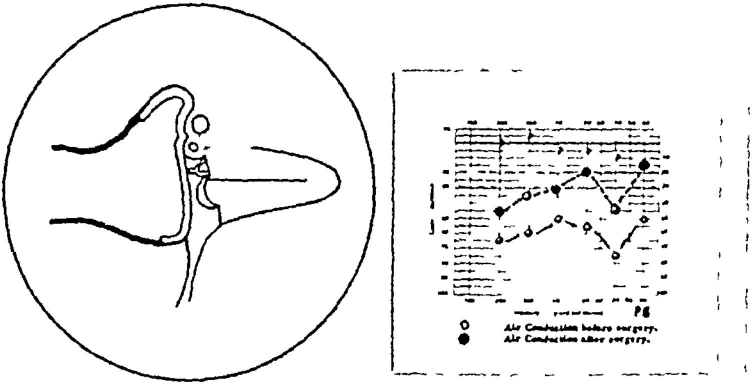
Mr BC—Age 25 Intermittent drainage from large central perforation and poor hearing all his life Patch test failed to raise air conduction, and demonstrated non-functioning ossicular chain.
Rx: Erosion of long process of incus was found in surgery, and a Type II Tympanoplasty was done

Fig 6

Technique—the graft is placed so as to contact the long process of the incus, thereby transmitting its vibrations directly to the incudostapedial joint

Type II-B (See Fig 6) Pathology—necrosis of the long process of the incus is present with loss of the true incudostapedial joint Fibrous adhesions across the defect between the shortened incus and stapes head do not act as a satisfactory incudostapedial joint in the transmission of sound impulses The accepted procedure in this situation has been to remove the ossicles in conjunction with a radical mastoidectomy and do a Wullstein Type III tympanoplasty In the absence of cholesteatoma we have found that this type of pathology can often be handled by modification of Wullstein's Type II tympanoplasty This technique has the following advantages

1 It can often be done directly through the external auditory canal as in myringoplasty or Type I tympanoplasty If the status of the mastoid is unsure, exploration of the mastoid, including the epitympanum may be done, leaving the bony external auditory canal intact If the epitympanum is free of disease, it is often unnecessary to remove the incus



Miss PB Classical Radical Mastoidectomy cavity with a 55 db loss Stapes mobile Rx Tympanic graft used to bridge over middle ear and placed in contact with the stapes 27 db gain

Fig 7

2 It insures an adequate air space in the stapes area of the middle ear, allowing free mobility of the new tympanic membrane and stapes

3 Improvement of hearing may be greater than the average Type III tympanoplasty result

4 It may avoid the inherent disadvantages of a radical mastoid cavity, however, this technique may be applied when a modified radical mastoidectomy is necessary, if a small portion of the bridge is left intact

Technique—the denuded tympanic remnant is raised from the annular sulcus posteriorly, and the incudostapedial joint area is exposed by wide removal of bone in the annular area At this time the round window area may be inspected and mobility of the stapes determined

When the graft is applied the denuded remnant of the drum and graft are depressed and packed lightly in place so as to contact the shortened long process of the incus, as well as the head of the stapes, thus the graft bridges from the annulus anteriorly to the malleus, to the incus and stapes, and back onto the posterior wall of the canal

Type III Pathology—Destruction of the ossicular chain is present, usually due to erosion by cholesteatoma The stapes is intact and is mobile or may be mobilized There is loss of the posterior and superior canal wall, because a radical mastoidectomy is necessary or has been done previously The annulus has been preserved and the Eustachian tube is functioning

Technique—all pathological processes are removed from the middle ear and mastoid The round and oval windows, including stapes mobility, are investigated A tympanic skin graft is applied so that it bridges from the tympanic remnant or annulus to the floor of the attic and facial ridge The graft is packed gently into contact with the head of the stapes in order that vibrations are transmitted directly to the stapes, affording a columella effect, similar to the middle ear conductive mechanism in the bird's ear

Type IV Pathology—Destructive processes similar to Type III except that the crura of the stapes are missing, the footplate is mobile, or a mobile oval window membrane is present

Technique—round window protection is achieved by bridging the skin graft from the annulus to the promontory, leaving the oval window exposed to direct vibration of sound

Type V Pathology—In addition to the pathological changes found in Types III and IV, the oval window is nonfunctional because of *irreversible fixation* of the stapes, or fibrosis

Technique—after fenestration of the lateral semicircular canal, the tympanic graft is applied to bridge across the middle ear space onto the floor of the attic, covering the fenestra *in the lateral semicircular* canal

SUMMARY

1 The general principles and basic techniques of tympanic skin *grafting* have been described

2 The modifications of this basic technique into the five types of tympanoplasty have been discussed

3 Preliminary preoperative procedures, including selection of patients for tympanoplasty, have been described

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ANNUAL OTOLARYNGOLOGIC ASSEMBLY UNIVERSITY OF ILLINOIS

The University of Illinois College of Medicine Department of Otolaryngology announces its Annual Otolaryngologic Assembly from September 29 through October 5, 1958 The Assembly will consist of an intensive series of lectures and panels concerning advancements in otolaryngology, and evening sessions devoted to surgical anatomy of the head and neck and histopathology of the ear, nose and throat Interested physicians should write direct to the Department of Otolaryngology, 1853 West Polk Street, Chicago 12, Ill

PRELIMINARY REPORT ON THE PATHOGENESIS OF DERMATOSES OF THE EXTERNAL AUDITORY CANAL

Twenty Cases of Acute Diffuse External Otitis, Due to Deep Infections *†

EDLEY H JONES, M D ,
Vicksburg, Miss ,
and
TOM D NORMAN, M D , (By Invitation),
Jackson, Miss

External otitis has always been a subject of particular interest to otologists, and more recently, to dermatologists During recent years many excellent investigative studies have been reported, yet only a casual survey quickly reveals that more are indicated and needed

As previous investigators have pointed out, the term "external otitis" embraces a variety of diseases that have little in common other than that they occur in the external ear Since the external ear, auricle and canal, is entirely covered by skin, these diseases must basically be designated dermatoses It is natural that otologists are primarily interested in the acute infections of the canal, and that dermatologists are primarily interested in other dermatoses of the auricle Geographical location and climate, more specifically, temperature, humidity, and exposure, are important factors Our Southern otologists annually see many cases of acute diffuse external otitis and furnuculosis with a sharp rise in the case load shortly after the opening of the swimming season, and

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*Read at the meeting of the Southern Section of the American Laryngological Rhinological and Otological Society Inc. Memphis Tenn Jan 24 1958

†From the Division of Otolaryngology Department of Surgery and the Department of Pathology University of Mississippi Medical Center Jackson Miss

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this experience is reflected in their studies and reports, our Northern colleagues in drier, cooler climates see fewer of these cases, and are more concerned with the other dermatoses

Reviews and discussions of the subject are hampered by the lack of a simple classification that is definite, clearly understood and generally accepted Senturia[3] published a detailed classification in his book, "Diseases of the External Ear," yet his introduction of it indicated he was not entirely satisfied with it, and it could hardly be called simple

For the purpose of this presentation we will employ the following etiological classification

Acute Diffuse External Otitis

I Dermatoses due to infection

A Superficial—*1* Bacterial, *2* Viral, *3* Fungal

B Deep—*1* Bacterial, *2* Viral, *3* Fungal

II Other dermatoses

Our presentation will be confined to those cases due to deep bacterial infections We consider furunculosis a progressive development and accompaniment of acute diffuse external otitis, due to furuncle-forming bacteria These cases are the result of Gram-positive bacterial infections, Gram-negative infections are usually superficial

Our interest in this phase of this subject was aroused by Sophian and Senturia's[4] detailed report of five biopsies of acute diffuse external otitis They commented on finding dilatation of the capillary and arteriolar vessels, endothelial swelling, hyperplasia and sometimes thrombosis and necrosis, noting that these vascular reactions are usually associated with toxic or allergic reactions rather than with pyogenic infections Further they noted a high eosinophilia (average 24 per cent) in the inflammatory exudate in the tissues While they pointed out that their findings did not necessarily indicate that the inflammatory process was allergic, they recognized that "certain clinical and pathological aspects—were—compatible with a state of sensitization "

One of us has studied allergy for the past 30 years and is keenly aware of the importance of allergy in otolaryngology, but could not accept such findings as typical of acute diffuse external otitis. Although the usual data were presented they did not include any history or indication as to whether those patients had an allergic background, whether they had been given previous local treatment that could have caused a complicating contact dermatitis, nor did they include any bacteriologic, cytologic or hematologic studies.

Our search of the literature at that time failed to reveal any other report of biopsies of cases of acute diffuse external otitis. Later Shelly and Perry[2] published an interesting investigative study on the experimental production of external otitis, reporting over 70 biopsies. Obviously, we cannot use them for direct comparison with our material.

In 1956 we studied biopsies and white blood counts of three cases of acute diffuse external otitis, one complicated with furuncle formation (previously briefly reported[1] but included in this study). These findings were quite different from those reported by Sophian and Senturia,[4] and prompted us to continue our studies in this field.

MATERIALS AND METHODS

To date we have studied biopsies of 27 cases. We do not have complete data on all of these but can fully report 20 cases, 12 of which were complicated with furunculosis. One patient was seen in the University Out-Patient Clinic, but the other 19 were private cases. Insofar as possible they were taken consecutively, as they presented themselves, excepting only young children, unusually apprehensive patients, and those who came in at the very end of the office hours. The biopsies were taken with the patients' knowledge and permission. Approximately 0.5 ml of 2 per cent xylocaine with 1:50,000 epinephrine was slowly injected 3 to 5 mm anteriorly to the chosen site, after five minutes an elliptical V-shaped section, 2 or 3 mm wide, and 4 to 6 mm long and extending down to the cartilage, was removed. The specimen was fixed in 10 per cent formalin, sections 5 micron thick were made, this experience is reflected in their studies and reports, our Northern colleagues in drier, cooler climates see fewer of these cases, and are more concerned with the other dermatoses

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	Case Number	Race	Sex	Age	White Blood Count							Furuncle	Month	Pathological Studies (Estimates)			
					Total	Segs	Bands	Lymphs	Monos	Bas	Eos			Segs	Monos	Eos	Severity of Inflammation
														noted in tissues			
1	56-67	W	M	45	16 700	70	10	10	6	1	3		Aug	20	80	1	Moderate
2	56-68	C	M	15	18 300	60	10	25	5	-	-		Aug	50	50	1	Moderate
3	56-69	W	M	12	7 700	49	7	29	11	1	9	X	Aug	75	25	10-15	Moderate
4	56-184	W	F	28	8 400	60	-	32	2	-	6		Sept	40	60	10-15	Moderate to severe
5	56-185	C	F	45	10 100	58	-	39	3	-	-	X	Nov	75	25	0-1	Moderate to severe
6	57-36	W	M	58	9,800	61	2	23	4	-	10		Nov	50	50	2-5	Slight to moderate
7	57-96	W	F	30	11 800	69	8	21	1	-	1	X	Jan	60	40	0-1	Moderate
8	57-97	W	F	67	8,400	59	-	35	2	-	4	X	Dec	90	10	0-1	Moderate
9	57-106	W	M	22	10 200	66	-	26	1	-	7		May	50	50	0-1	Slight
10	57-107	C	F	23	9 600	61	-	36	2	-	1	X	May	75	25	1	Severe
11	57-109	C	F	26	10 600	69	-	27	1	-	3	X	Apr	75	25	1	Slight to moderate
12	57-111	W	F	40	10 900	63	8	24	2	-	3	X	Feb	80	20	0-2	Moderate to severe
13	57-129	W	M	19	11 300	52	6	30	4	-	8	X	July	75	25	0-1	Severe
14	57-131	W	F	23	19,400	56	12	29	-	-	3		July	30	70	0	Slight
15	57-132	W	M	25	14 700	54	9	31	3	-	3	X	July	50	50	0-1	Severe
16	57-133	W	M	34	15 500	68	11	12	5	-	4		July	80	20	0	Moderate
17	57-134	W	M	16	10,900	42	16	29	6	-	7	X	July	75	25	1-3	Severe
18	57-135	C	F	16	16 700	56	5	37	-	-	2	X	July	50	50	0-1	Slight to moderate
19	57-136	W	M	13	12 800	79	6	14	1	-	-	X	July	80	20	0	Severe
20	57-137	W	F	22	9,300	48	9	34	2	1	6		July	75	25	0	Moderate

Chart 1

some semiserially Slides of all cases were routinely stained with hematoxylin and eosin, but slides from six biopsies also were stained by Giemsa's technique and MacCallum's modification of Goodpasture's Gram's stain A total and differential white blood count was routinely made on each patient

A statistical analysis of these cases reveals their ages ran from 12 to 67, younger patients were purposely not included Only 25 per cent were in the colored race, which confirms previous observations by other otologists The incidence in sexes was identical, but it is interesting to note that the seven cases following swimming were all males, five in their 'teens, while seven of the eight who gave a history of previous involvement were females Furuncle formation was noted at the time of first examination in 12 of the 20 cases, eight of the 15 whites, and four of the colored Oddly enough, a history of trauma was obtained in only two cases, both white adults, one male and one female Almost one-half were patients in their third decade, but there was at least one in each of the second, fourth, fifth, sixth and seventh decades Patients were seen in every season and almost every month, with more than one-half in July and August

CHART 2

		Race		Sex		Age					
	Total	W	C	M	F	11 20	21 30	31 40	41 50	51 60	61 70
Incidence of Cases	20	15	5	10	10	6	9	1	2	1	1
Cases Following Swimming	7	6	1	7	–	5	1		1		
History of Pruritus or Previous Involvement	8	6	2	1	7		3	1	2		1
History of Trauma Picking Ear	2	2		1	1		1			1	
Furuncle Noted	12	8	4	5	7	5	4	1	1		1

PATHOLOGIC STUDIES OF BIOPSIES

Histologic Characteristics of the Inflammatory Reaction

The degree of the inflammatory reaction, as determined by the number of inflammatory cells and the basic alterations of the tissues, varied with different patients, but for the most part was moderately severe (see Fig 1) Although round cells (mostly lymphocytes) were predominant in three patients, the usual situation was a great preponderance of polymorphonuclear leukocytes (see Fig 2) These cells usually infiltrated most areas of the biopsy specimens diffusely, but in some locations they were more concentrated, occasionally around skin appendages There was no perivascular collection of the inflammatory cells

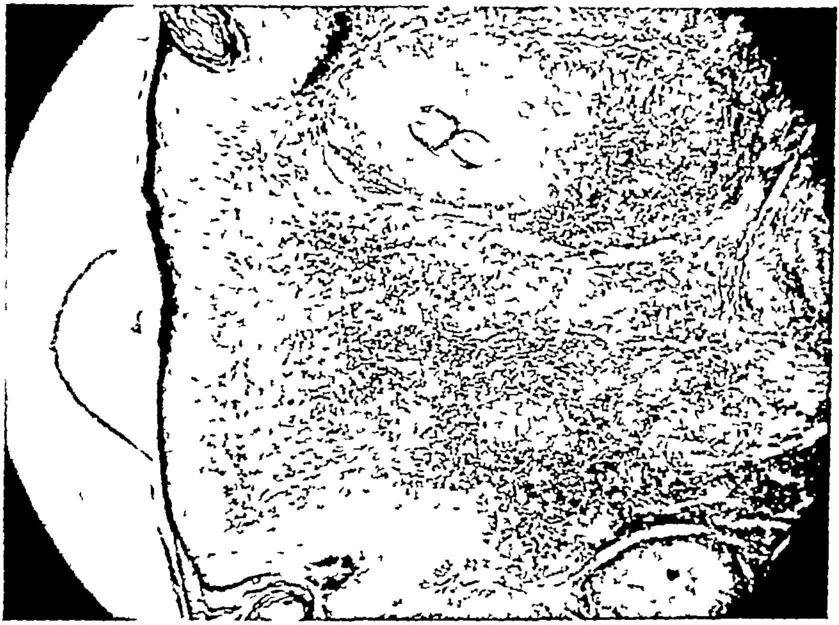

Fig 1 (E-56-67) Moderately severe inflammatory reaction in connective tissue under epidermis and around hair follicles and sebaceous glands Only a few inflammatory cells are seen in the epithelium and there is moderate parakeratosis Hematoxylin and eosin stain X-60

Eosinophils were scarce in most of the tissue sections, but in two patients these cells were significantly increased When present, the eosinophils were found throughout the inflammatory reactions

Focal tissue destruction in the dermis, with infiltration of solid sheets of neutrophilic leukocytes, was present in several patients (see Fig 3) These furuncles were relatively small and were surrounded by inflammatory cells of the type seen in other areas of the tissue in that patient A few eosinophils were present in the exudate within the furuncles in biopsy material in which those cells were present elsewhere

Gram-positive bacteria in clumps (see Fig 4), morphologically similar to staphylococci, were found deep in the tissue from two patients Similar bacteria were present in detached keratin and cellular debris in one of these biopsies and two others

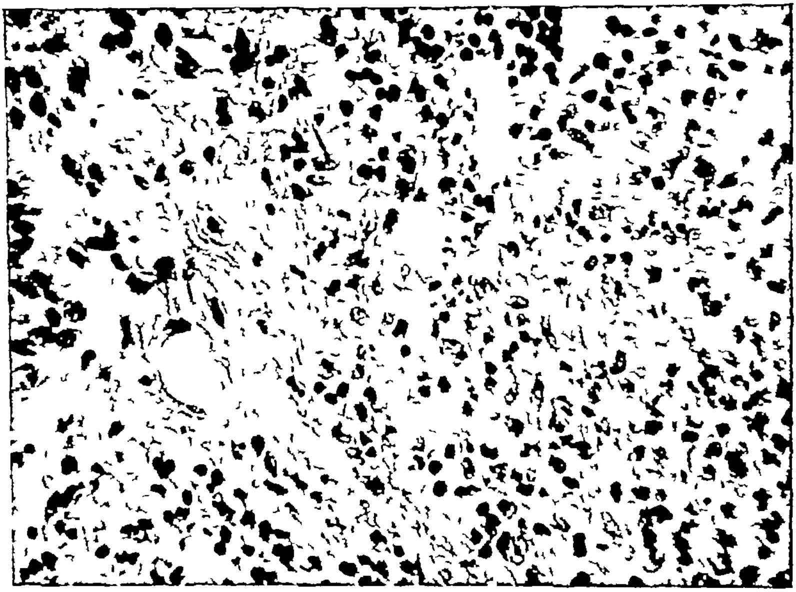

Fig 2. (E-56-67) Polymorphonuclear inflammatory cells in tissue illustrated by Fig 1. Hematoxylin and eosin stain X-330

Infiltration of the epidermis was limited to neutrophilic leukocytes and an occasional eosinophil, noted in areas of spongiosis and vesiculation (see Fig 5), or rarely within hair follicles (see Fig 6), giving the appearance of microabscesses within the epidermis, these cells also were noted in the most superficial keratin layer and in fragments of keratin debris

The material from one patient was characterized by the presence of many large multinucleated giant cells of the type commonly seen with foreign bodies Many cells of varied type were seen around these giant cells

Epidermis

In most of the sections there was a slight thickening of the epidermis, with some hyperkeratosis, parakeratosis, and slight hyperplasia of the basal layer Elongation of the rete pegs of a mild degree was commonly present Spongiosis (edema) of the epidermis was frequent, being absent completely in only three patients Vesiculation of varying degree was often present and, as expected, appeared to be a progression from the severe stage of spongiosis (see Fig 5) As noted previously, neutrophils and a few eosinophils were in these areas Microabscesses (see Fig 6), appearing to result from intrafollicular inflammation and quite different from the vesicula-

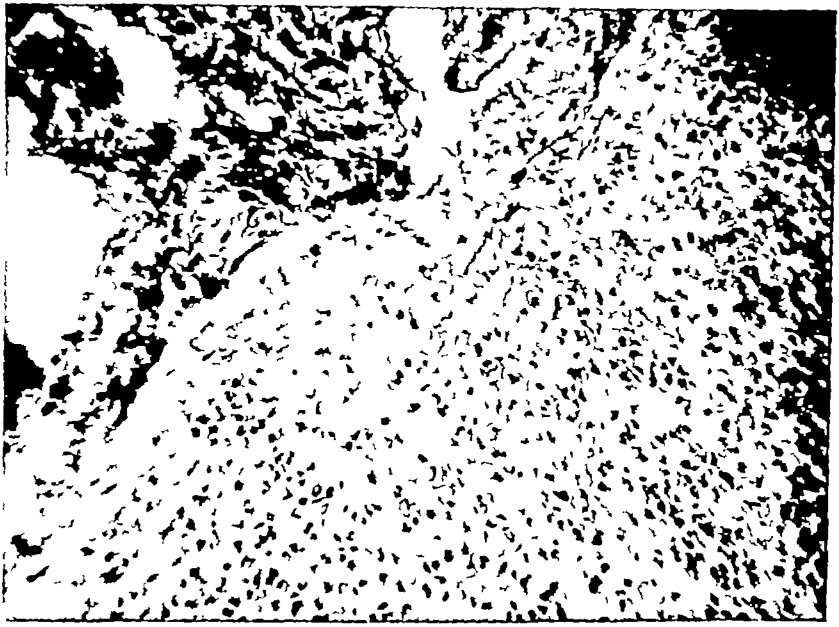

Fig 3 (E-57-111) Purulent exudate present in a furuncle Hematoxylin and eosin stain X-230

tion, were seen rarely Degeneration of the epidermis and neutrophilic infiltration were present over the furuncles Follicular hyperkeratosis was present to some extent in all of the tissue except that from one patient

Skin Appendages

In general the hair follicles shared the changes of the epidermis, though to a lesser degree Spongiosis and vesiculation were prominent in material from some patients and the inflammatory exudate of the dermis was occasionally concentrated about the hair follicles Neutrophils, and rarely eosinophils, were present in the areas of spongiosis and vesiculation Microabscesses within follicles have been described above

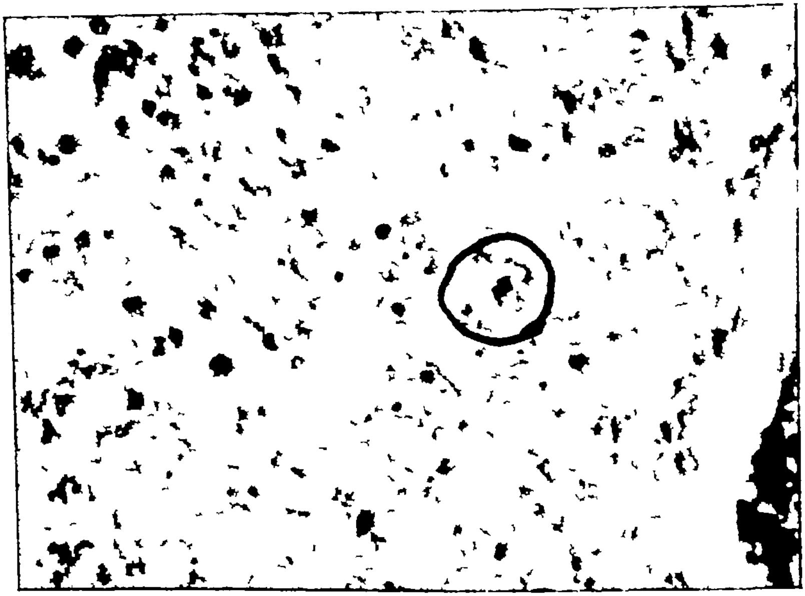

Fig 4 (E-56-185) Small clump of gram-positive cocci (upper center) deep in skin of ear Gram's stain X-450

The apocrine (ceruminous-producing) glands varied in the height of their epithelium, consistent with known variation due to secretory activity In the vicinity of the most severe inflammatory reactions the glandular epithelium was distort-

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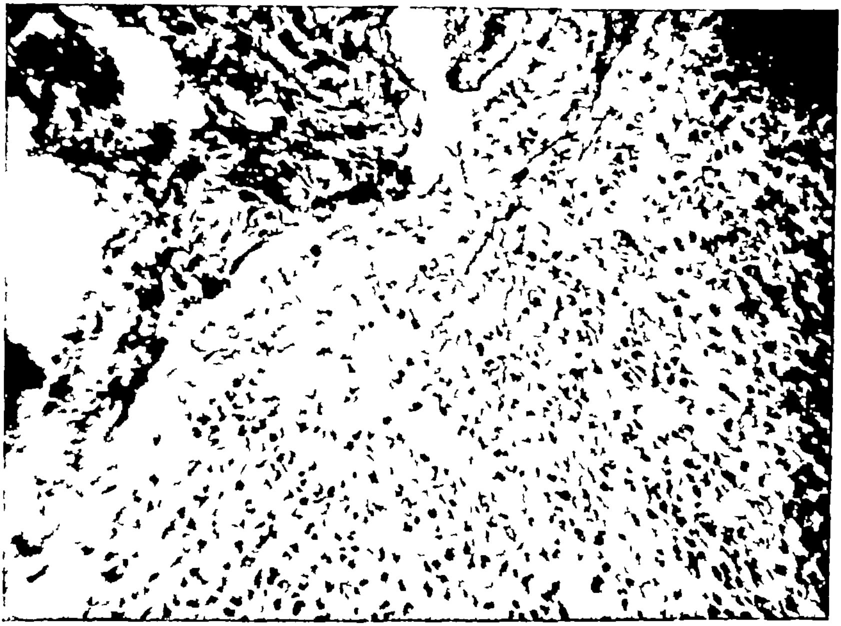

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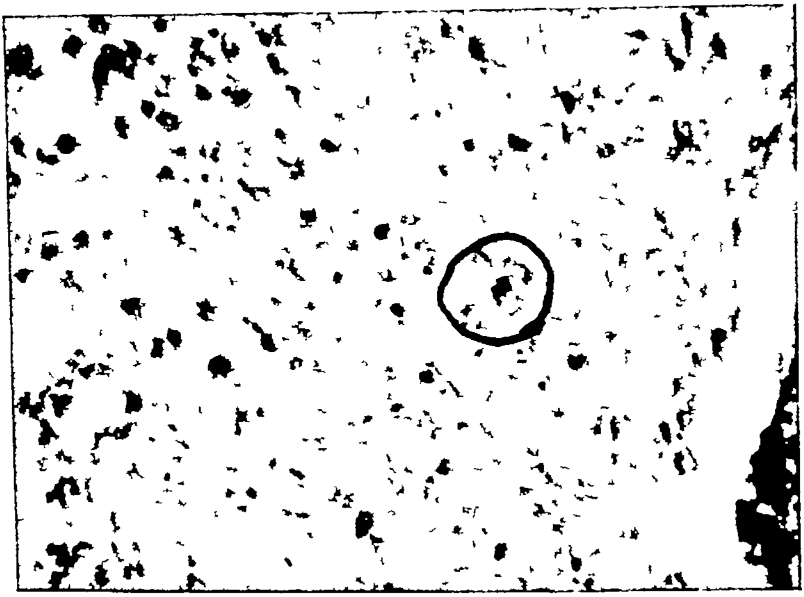

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The apocrine (ceruminous-producing) glands varied in the height of their epithelium, consistent with known variation due to secretory activity In the vicinity of the most severe inflammatory reactions the glandular epithelium was distorted, and inflammatory cells, usually only a small number, were present within the epithelium and the lumens The glands were badly damaged or destroyed occasionally in the vicinity of the most severe inflammation (see Fig 7) Dilatation of the ducts either was not present or was slight

Inflammatory cells in and around the sebaceous glands were sparse Retention of sebum was present to a slight degree in some glands

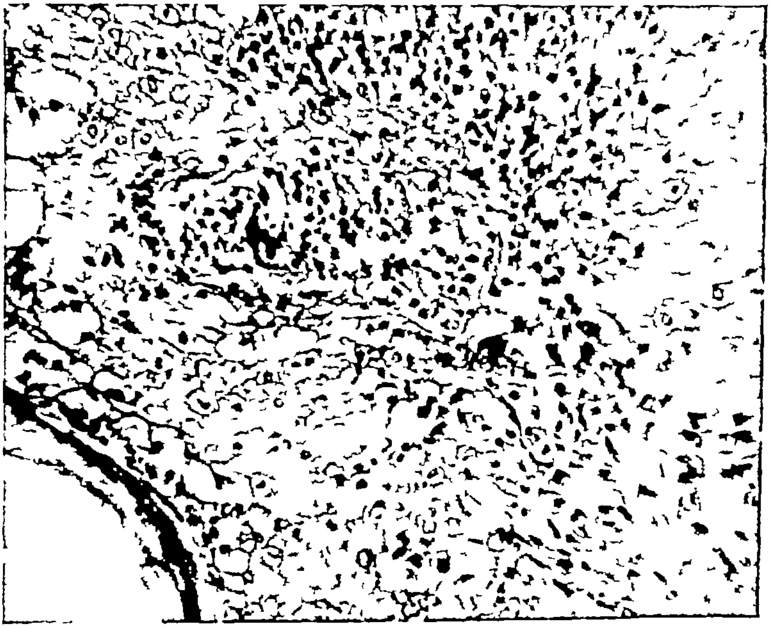


Fig 5 (E-57-136) Polymorphonuclear leukocytes in areas of spongiosis and vesiculation Hematoxylin and eosin stain X-230

Dermis

The general inflammatory reaction in the dermis has been described above This was accompanied by some degree of edema in most of the material, most prominent in the upper dermis Brown pigment which gave a negative reaction to the iron stain was present in material from two patients

Dilatation of blood vessels was noted, especially in the upper dermis Endothelial swelling was prominent, varying in severity with the amount of inflammation present In some vessels the lumen was narrowed by the swollen endothelial cells No vascular thrombi were noted, necrosis of blood vessels was also absent

HEMATOLOGIC CORRELATION

A scattergram plotting the total white counts of the peripheral blood against the percentage of neutrophils in the tissues reveals a fairly consistent finding of more than 50 per cent segmented cells in the tissues when the total count was over 10,000 A second scattergram plotting the percentage of eosinophils in the peripheral blood against the percentage of eosinophils seen in the tissues failed to reveal any correlation, comparatively few eosinophils were noted in the tissues, regardless of the percentage found in the peripheral blood

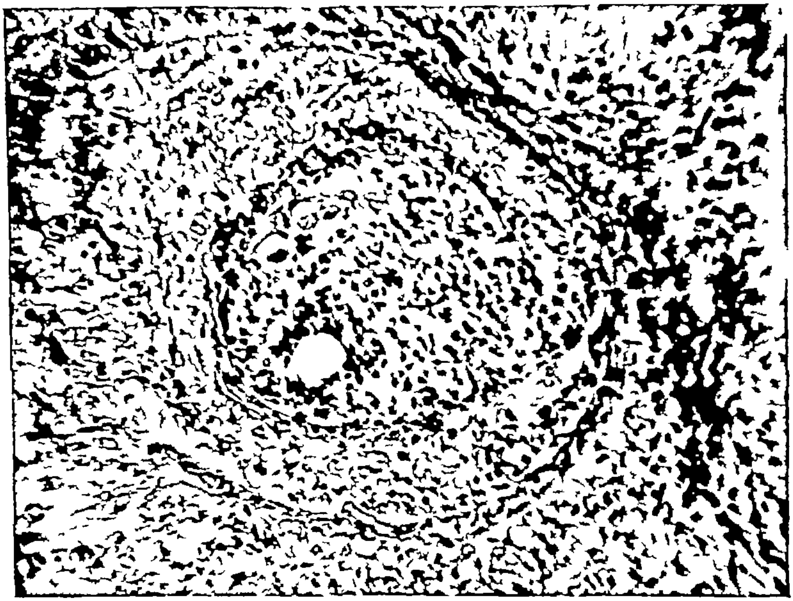


Fig 6 (E-57-136) Leukocytic infiltration of polymorphonuclear type in hair follicle Hematoxylin and eosin stain X-230

DISCUSSION

The inflammatory reaction present in these patients differed from that described by Sophian and Senturia[4] in that there was significant tissue eosinophilia in only two specimens Furuncle formation, conspicuous in our material, was not described in their studies Sophian and Senturia also described vascular necrosis and thrombosis, neither of these changes was present in our material With the exception of tissue eosinophilia in two cases there was nothing in the histologic features of the inflammatory processes studied by us to suggest a hypersensitivity mechanism On the contrary, the features in general are those one would expect to find in an infectious process, with localization and furuncle formation in specimens from some patients It is possible that in the two patients in whom there was tissue eosinophilia the basic changes were produced by hypersensitivity, with a com-

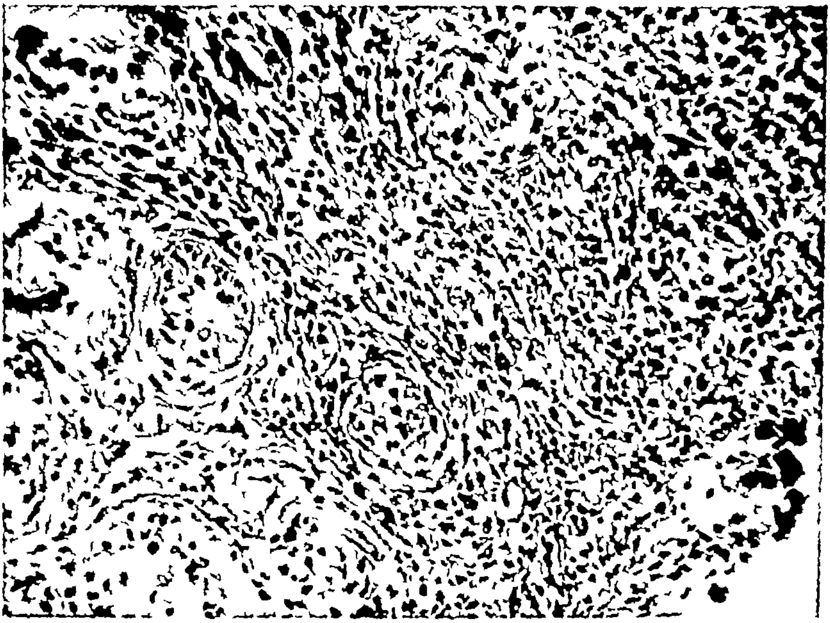
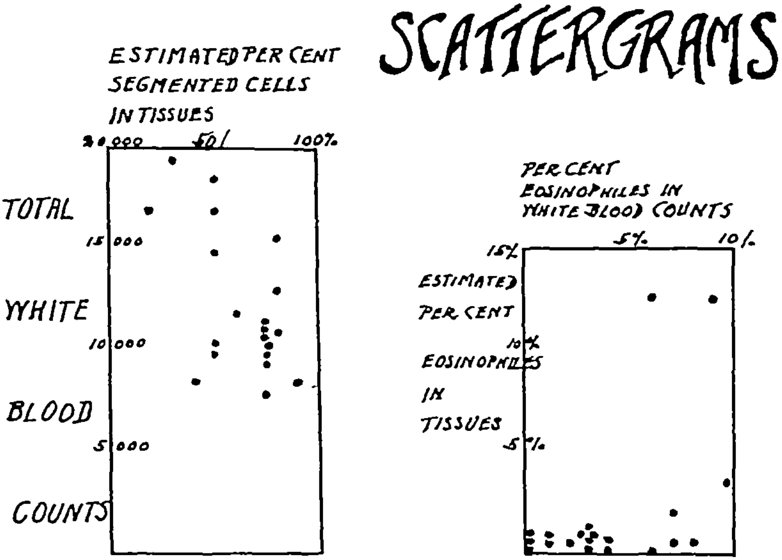


Fig 7 (E-57-107) Severe inflammatory reaction in and around apocrine glands Hematoxylin and eosin stain X-230

plicating infectious process One of these patients had a definite furuncle

Shelley and Perry,[2] in an experimental study of the effect of various materials on the human external ear, described spongiosis and vesiculation of follicles as characteristic of a low grade contact dermatitis, produced by a 1 100 acetone solution of 3-n-Penta Decyl-catechol, however, they also noted



a similar change in the skin of ears treated with an irritant, 2 to 4 per cent formalin The follicular alterations described in those experiments were similar to the spongiosis and vesiculation present in the follicles of our material, in our studies, however, these changes were even more pronounced in the epidermis proper In view of the fact that spongiosis and vesiculation were produced by entirely different chemicals in their studies, and are present in a variety of skin diseases, it seems unlikely that these follicular or epidermal changes are a specific characteristic of allergic disease of the external ear

CHART 3

Vicksburg, Mississippi—Ground Elevation Above Sea Leval—234 Feet

	1956					1957							Average	
Year and Month	A	S	O	N	D	J	F	M	A	M	J	J		Total
Relative Humidity	59	57	55	55	64	68	62	55	55	57	61	60	59	
Average Temperature	82.3	75.4	68.9	55.2	56.9	49.1	57.8	56.5	67.0	73.6	79.1	82.2	67	
Incidence of Cases ..	3	1		2	1	1	1		1	2		8		20
Following Swimming ..	3											4		7
With Furuncles ..	1			1	1	1	1		1	1		5		12

Statistics on humidity and temperature obtained through the courtesy of Mr Ernest Sherrill Meteorologist Weather Bureau Vicksburg

The one biopsy specimen of the present study in which a giant cell reaction was present is of interest. It seems likely that they resulted from damage to sebaceous glands with loss of sebum into the tissue. Although no foreign material could be demonstrated, it is possible that an unknown material had been introduced into the tissues of the ear.

Humidity, temperature and swimming are currently considered important factors in the production of this type of external otitis, and these studies may add some support to this opinion. The relative humidity is rather high in this area throughout the year and does not vary greatly, while there is no direct relationship between high humidity and incidence of cases, the constant high humidity may explain the incidence of cases during the Winter months. Apparently higher temperatures in Summer had no influence other than to encourage swimming but, again, the average temperature in this area is comparatively high. The incidence following swimming is obvious.

The occurrence of furunculosis throughout the year adds support to our opinion that furunculosis is a stage in the inflammatory process of acute diffuse external otitis due to or complicated with infection by furuncle-forming bacteria.

CONCLUSION

We have presented detailed studies of the pathologic findings in 20 cases of acute diffuse external otitis due to infection, 12 of which were clinically complicated with furunculosis, and have correlated them with total and differential white blood counts.

These studies have been interesting to us, but we do not consider them final in any sense. The obvious differences between our findings and those of Sophian and Senturia,[4] and the known influence of temperature, humidity and exposure, adds support to the theory that the clinical picture of this type of acute diffuse external otitis may be varied in different geographical areas and climates. We feel that studies from other areas are indicated, and hope that other otologists and pathologists will join us in continuing these investigations

Our appreciation is extended to Mr John Dickson, Chief, Department of Medical Illustration, University of Mississippi Medical Center, for the microphotographs used in this paper

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POST GRADUATE COURSE UNIVERSITY OF ILLINOIS

The next postgraduate course in Laryngology and Bronchoesophagology to be given by the University of Illinois College of Medicine is scheduled for the period October 27 through November 8, 1958, under the direction of Dr Paul H Holinger

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PATHOLOGY OF THREE HUNDRED CLINICALLY BENIGN LESIONS OF THE VOCAL CORDS*

G. S. FITZ-HUGH, M.D.,†
DAVID E. SMITH, M.D.,‡ (By Invitation),
and
A. T. CHIONG, M.D.,† (By Invitation),
Charlottesville, Va.

The survey of this group of patients was prompted by Salinger's provocative article, published in THE LARYNGOSCOPE in 1956, pertaining mainly to the nomenclature of benign tumors of the larynx. From the material accumulated, and the information available in the articles mentioned in the bibliography,[2-30] we have made an attempt to clarify our thinking in regard to the classification of abnormal but benign changes in the tissues of the vocal cords. As will be seen, it is evident that the results of the survey will be of benefit to us, and perhaps may be of interest to others.

We decided to study 300 consecutive cases (May, 1949, through May, 1957, an eight-year period), in which material was removed from the vocal cord for therapeutic and diagnostic reasons. The laryngoscopies and excisions of tissue were performed by members of the Department of Otolaryngology, of the University of Virginia Hospital, except in two instances (tissue referred by otolaryngologists in neighboring cities), and all the material was examined by the members of the Department of Pathology of this institution. A number of individuals participated in the above procedures, and this is one of the reasons for the confusion that was apparent in the presentation of the material to the pathologists and in the reporting of the results of their examinations.

As will be noted, the survey was initiated by first review-

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*Read at the meeting of the Southern Section American Laryngological Rhinological and Otological Society, Inc., Memphis, Tenn., Jan. 24, 1958.

From the Department of Otolaryngology† and the Department of Pathology‡ University of Virginia Hospital.

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ing the various interpretations of the tissues, as reported by the first pathologists, who were the ones designated to be the examiners of all the routine specimens received by the Department of Pathology at that particular time Consequently, the material was analyzed by many different pathologists of varying grades of experience in studying laryngeal structures It was shown, also, that this group seldom received an adequate clinical description of the section to be examined In the majority of cases the pathologist was aware only that the specimen was taken from the vocal cord

TABLE I—CLINICAL DIAGNOSIS

1	Undiagnosed (Tissue from Vocal Cord)	97
2	Polyp	57
3	Papilloma	26
4	R O Carcinoma	25
5	Granuloma	24
6	Juvenile Papilloma	12
7	Vocal Cord Nodule	11
8	Leukoplakia	10
9	Cyst	8
10	Laryngitis (Inflammation)	7
11	Singers' Nodule	5
12	Hyperkeratosis	4
13	Hemangioma	4
14	Benign Lesion	4
15	Keratosis	2
16	Mucosa	2
17	Ulcer (Inflammation)	1
18	Fibroma	1

This inadequacy is demonstrated in the details of the first Table, entitled, "Clinical Diagnosis" The form accompanying the section was usually completed by an assistant junior resident, the accurate record of the senior staff physician not being available This was mainly true in regard to the earlier patients in the group, the defection having been corrected later

Referring again to Table I, "Clinical Diagnosis," one will notice a large number in the undiagnosed category The tissue was sent to the pathologist with very meager details concerning the history, plus the notation only that it was from a vocal cord Further examination of this chart shows other evidences of lack of detail and care in stating the preoperative clinical diagnosis

Next, reference is directed to Table II, entitled, "Initial Pathological Diagnosis" One is impressed immediately by the numerous diagnoses made, and also by the similarity and minor variations in many of them These differences may be attributed in part to the lack of close contact between the laryngologist and the pathologist, in addition to the fact that the pathologist's interest was more general than specific as far as abnormal laryngeal tissues were concerned

TABLE II—INITIAL PATHOLOGICAL DIAGNOSIS

1	Polyp	81
2	Papilloma	42
3	Singers Nodule	36
4	Granuloma	23
5	Laryngitis (Inflammation)	17
6	Squamous Hyperplasia	13
7	Juvenile Papilloma	11
8	Granulation Tissue	10
9	Inflammation with Hyperplasia	10
10	Cyst	9
11	Hemangioma	8
12	Hyperkeratosis with Inflammation	5
13	Hyperkeratosis	4
14	Inflammation with Metaplasia	4
15	Dyskeratosis with Metaplasia	3
16	Hyperplasia with Metaplasia	3
17	Leukoplakia	2
18	Dyskeratosis	2
19	Hyperkeratosis with Hyperplasia	2
20	Fibrosis with Myxomatous Degeneration	2
21	Pachydermia	2
22	Myofibroma	2
23	Edema	2
24	No Pathological Change	2
25	Inflammation with Myxomatous Degeneration	1
26	Hyalinization with Myxomatous Degeneration	1
27	Hyperkeratosis with Myxomatous Degeneration	1
28	Hyperkeratosis with Cyst	1
29	Hemorrhage in Muscle Fibers	1

The same sections presented in Table II were re-examined by a pathologist (D S), who was specially interested in the subject of abnormal laryngeal tissue and its problem of nomenclature An attempt was made to re-analyze the entire

TABLE III—REVISED PATHOLOGICAL DIAGNOSIS

1 Laryngeal Nodules		134
Unqualified	128	
Qualified		
With Hemosiderosis	2	
With Hyperkeratosis	2	
With Granulomatous Features	1	
With Inflammation	1	
2 Inflammation		34
Unqualified	10	
Qualified		
With Granulation Tissue	13	
With Hyperkeratosis	8	
With Ulceration	2	
With Ulceration and Granulation Tissue	1	
(No cases of Specific Inflammation such as Tuberculosis, Blastomycosis, Syphilis, etc, included)		
3 Squamous Papillomas		28
Unqualified	26	
Qualified		
With Dyskeratosis	2	
(Includes Juvenile Papillomas)		
4 Laryngeal Polyps		27
Unqualified	18	
Qualified		
With Hyperkeratosis	1	
With Dyskeratosis	1	
Fibrous (Papillomas)	5	
Fibrous with Hyperkeratosis	2	
5 Epithelial Changes		25
Unqualified		
Qualified		
Hyperkeratosis	19	
Dyskeratosis	2	
Carcinoma in Situ	2	
Epidermoid Carcinoma	1	
Hyperplasia	1	
6 Cysts		12
Unqualified	4	
Qualified		
Columnar	4	
Mucous	3	
Squamous	1	
7 Pyogenic Granuloma		10
Unqualified	10	
8 Miscellaneous		30
Missing Specimens	15	
Inadequate Specimens	9	
Normal Mucosa	3	
Hemangioma	1	
Skin (error)	1	
Nodular Lymphoid Infiltration (Lymphosarcoma)	1	

group of 300 sections Fifteen specimens could not be located and were classified as missing in the miscellaneous category

The interpretations of this pathologist, working intimately with the laryngologists, offered an interesting study of the two groups, as recorded in Tables II and III These studies have resulted in a simpler rearrangement or classification of abnormal benign laryngeal lesions, which, we are hopeful, will be of value to our local laryngologists and pathologists in the future, perhaps also, benefit, as far as prognosis and treatment are concerned, may be forthcoming as a result of this arrangement

One may have noticed that in the collection of cases in this survey, no malignant neoplasms nor specific inflammatory processes of the mucous membranes are included Many carcinomas and a few cases of specific inflammatory lesions of the cords, such as tuberculosis and blastomycosis, were encountered during the years of the survey, but were eliminated, as our primary interest was in benign lesions with little specificity It was noted that apparently carcinoma of vocal cords was comparatively easy to diagnose, as when this diagnosis was made clinically, prior to histological examination, it was usually correct In turn, when doubt was exhibited by the request, "Rule out carcinoma," sent to the pathologist with the tissue, carcinoma was generally not present

TABLE IV—COMPARISON COMMONER LESIONS

Diagnosis	Original Path. Diag Number	Revised Path. Diag Number
1 Polyps	81	27
2 Papillomata (Adult and Juvenile)	53	28
3 Singers Nodules (Laryngeal)	36	134
4 Granulomata	23	10
5 Inflammations (Laryngitis)	14	34

As will be seen later, the pathologists had little difficulty in deciding upon the diagnosis of carcinoma, for in the approximately 300 examinations, only one fairly definite error in diagnosis was disclosed One specimen was called benign, but on second examination was thought to be unquestionably an epidermoid carcinoma

Some comments will now be made with regard to the various categories used in the classification Space does not permit a detailed study of all, only the commoner groups will be considered

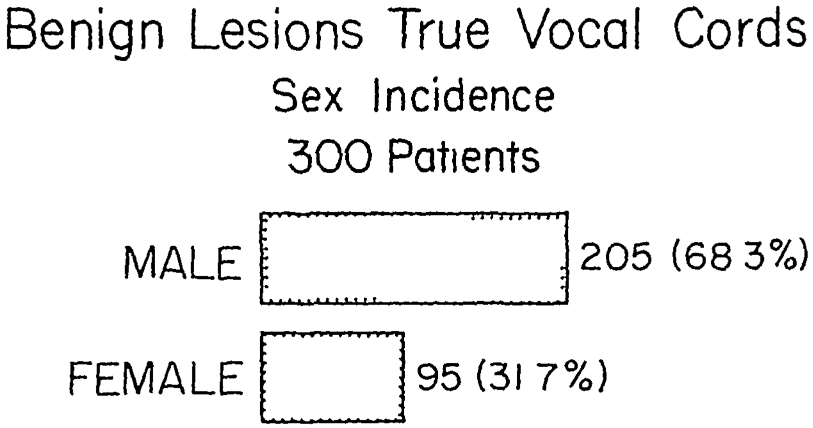

Fig 1

LARYNGEAL NODULES (VOCAL NODULE, SINGERS' NODE, CHORDITIS NODOSA, SCREAMERS' NODE, FIBROUS NODULE, CHORDITIS TUBEROSA, TEACHERS' NODE, ETC

In the initial pathologic diagnosis (Table II), 36 patients were considered to have singers' or laryngeal nodules When the same group of cases were re-examined by the second pathologist and laryngologist, the number in this category was increased to 134 patients, as will be noted in Table III This is not particularly surprising, as there is much confusion in the nomenclature and histological interpretation of tissue from the vocal cords which may be classified as laryngeal nodules or laryngeal polyps For instance, Stewart[1] does not mention laryngeal nodules in his 104 cases of benign tumors of the larynx, but does have 61 cases of "Inflammatory Polypus" Epstein[2] and his associates diagnosed 283 cases of laryngeal polyps in a group of 366 benign tumors, believing polyps, nodules, and polypoidal degenerations to be histologically identical non-neoplastic swellings of the membranous vocal cords Salinger,[1] on the other hand, found that his pathologists diagnosed no polyps and only three vocal nodules in a series of 232 consecutive laryngeal biopsies Undoubtedly, in our survey, Epstein and Stewart would have classified the majority of our nodular cases as polyps There are many variants of nodules and polyps which may be placed in either class, depending upon the impression of the pathologist, and which are essentially different manifestations of one and the same condition From our study, we must consider the laryngeal nodule as the commonest chronic benign lesion of the vocal cords for which tissue is removed for diagnostic and therapeutic measures

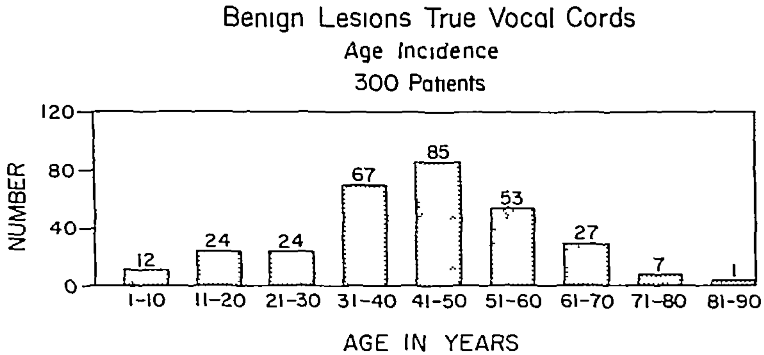

Fig 2

A laryngeal nodule is a "specialized reaction to trauma" (Ash[6]), which is basically a localized nodular or polypoid area of degeneration of the lamina propria These reactions of degeneration include fibrosis, edema, a myxoid appearance, fibrinous deposits, and even hemorrhage, necrosis and calcification The overlying epithelium may be atrophic or slightly hypertrophic and hyperkeratotic Kelly and Craik,[7] Ash and Schwartz,[8] have described these variations in some detail We have followed their descriptions to a large extent in an effort to attain histological accuracy and simplicity The edematous, fibrous, angiomatous and myxomatous characteristics are shown in the photomicrographs

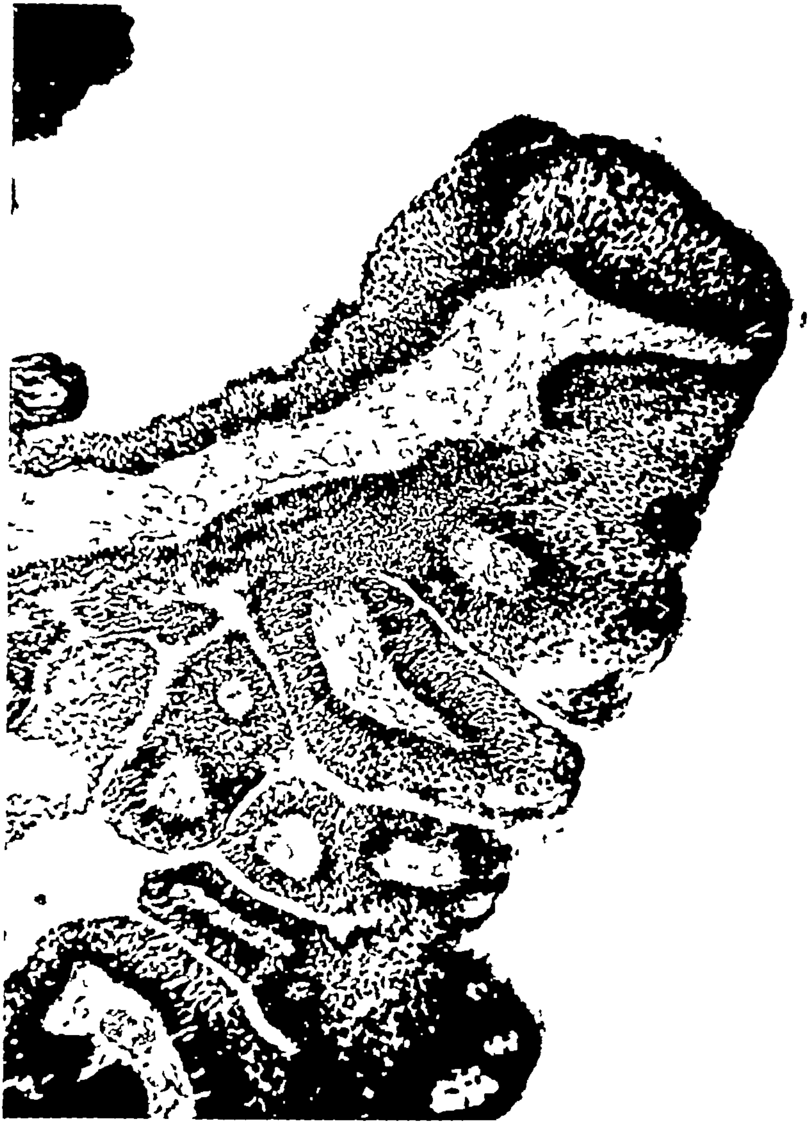

Fig. 3 Squamous papilloma of the larynx with redundant papillae of acanthotic squamous epithelium over a delicate and rather scanty stalk of fibrous tissue (H and E 110×)

LARYNGEAL POLYPS

As in many of the categories proposed in our survey, again there were differences in the interpretation of the tissue presented to the pathologist, as far as the entity, laryngeal polyp, was concerned In the first group examined (Table II), 57 cases were diagnosed as laryngeal polyps This number was reduced (see Table III) to 27 cases when the tissues were re-examined Some were transferred to the laryngeal nodule category In some classifications, the laryngeal polyp is considered a stage in the development of the laryngeal nodule, and vice versa

We have used this term for lesions that are polypoid, or projecting masses, composed principally of a central core of fibrous connective tissue of greater density than normal lamina propria and covered by a normal or only slightly hyperplastic or hyperkeratotic epithelium The origin is from the subepithelial or Reinke's spaces It seems to contrast with the papilloma, in that the stroma is predominant in the polyp, while the epithelium is predominant in the papilloma Although the first stage (Ash) of the laryngeal nodule consists of subepithelial fibrosis, the early laryngeal nodule is not polypoid and, therefore, differs from this lesion we are calling a polyp Polyps are pedunculated and may exhibit angiomatous and myxomatous characteristics Polypoid degenerative changes are diffuse and sessile, and are sometimes described as laryngeal nodules

INFLAMMATIONS

The nonspecific chronic inflammatory group, numbering 34 cases, offered much less confusion and difficulties in the pathologic diagnosis than those classes previously considered The histologic signs of inflammation are quite evident, and the number of cases of laryngitis with the various qualifications are similar to Tables II and III

SQUAMOUS PAPILLOMATA

The larger number of papillomata were so designated by the pathologist who performed the initial examinations After

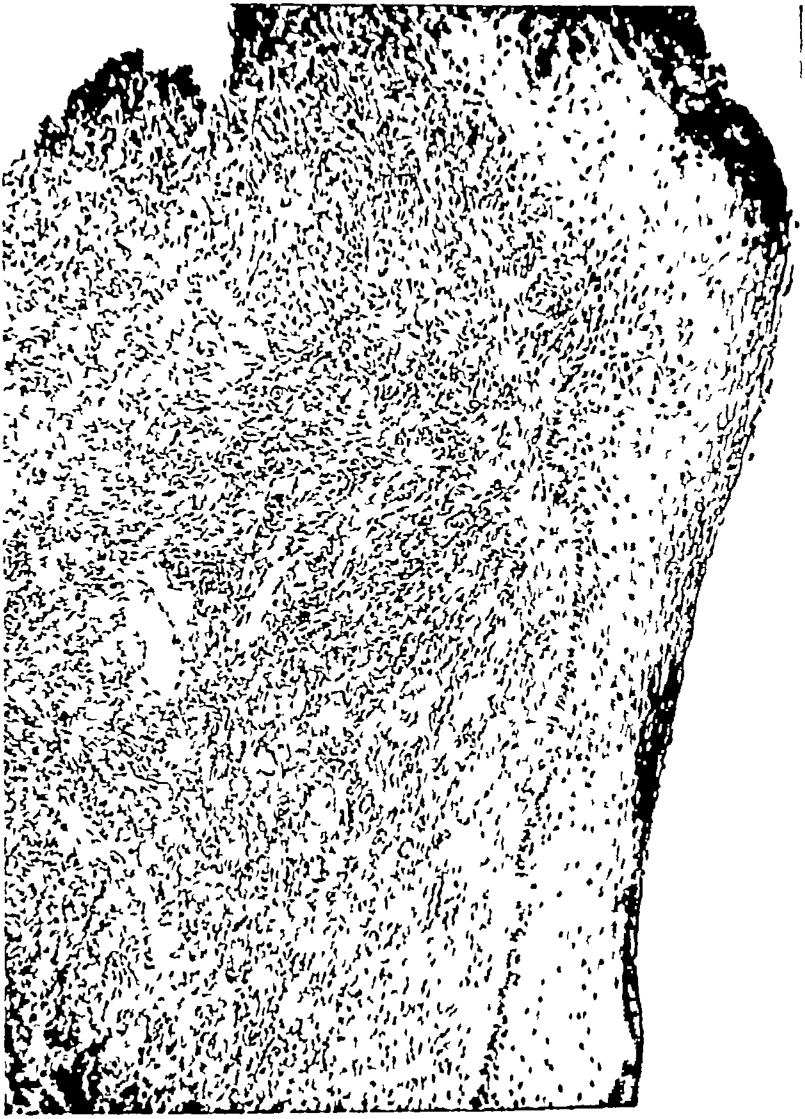

Fig 1 Pyogenic granuloma of the larynx composed of a cellular granulation tissue with hemosiderin under a slightly hyperplastic and hyperkeratotic epithelium (H and E (110X)

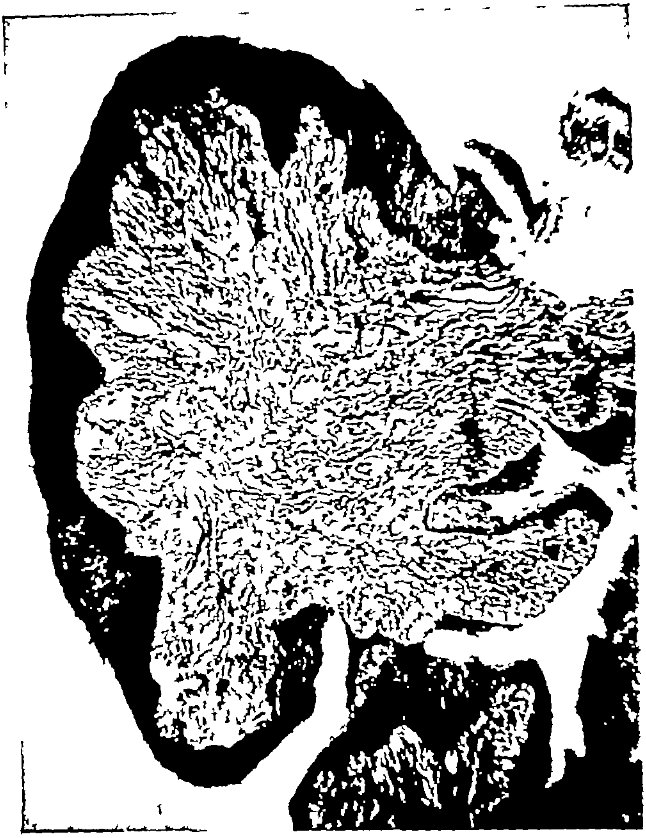

Fig 5 Polp of the larynx with pedunculated configuration dense fibrous stroma and only slightly thickened or hyperkeratotic overlying squamous epithelium This lesion is not as characteristically papillary in outline as is the papilloma (H. and E 60X)

further consideration, according to the scheme previously outlined, the number in this section was reduced, with differences favoring mainly the nodular group

The histological diagnosis was made on the basis of a papillary lesion, either pedunculated or sessile, composed of thick folds of hyperplastic, acanthotic, squamous epithelium, arranged over delicate, thin cores or processes of vascularized connective tissue, essentially similar to normal lamina propria In view of our present knowledge, cases of this lesion can be divided, clinically but not histologically, into

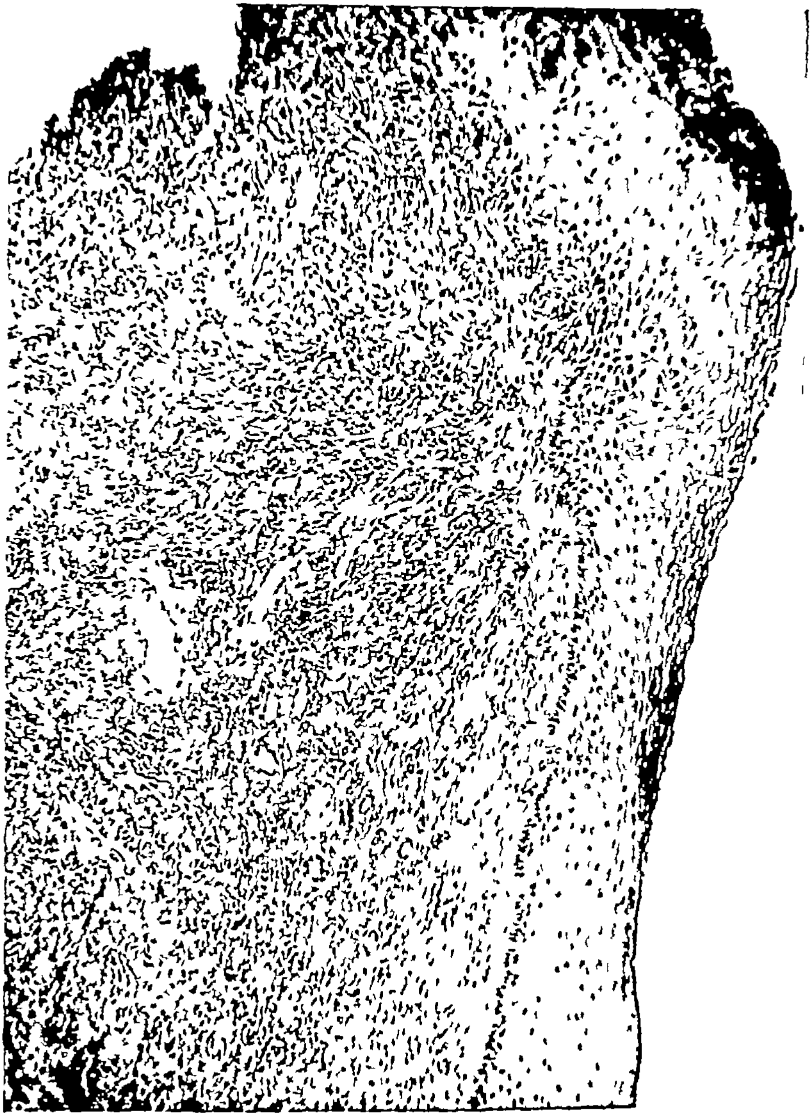

Fig 4 Pyogenic granuloma of the larynx composed of a celular granulation tissue with hemosiderin under a slightly hyperplastic and hyperkeratotic epithelium (H and E (110X)

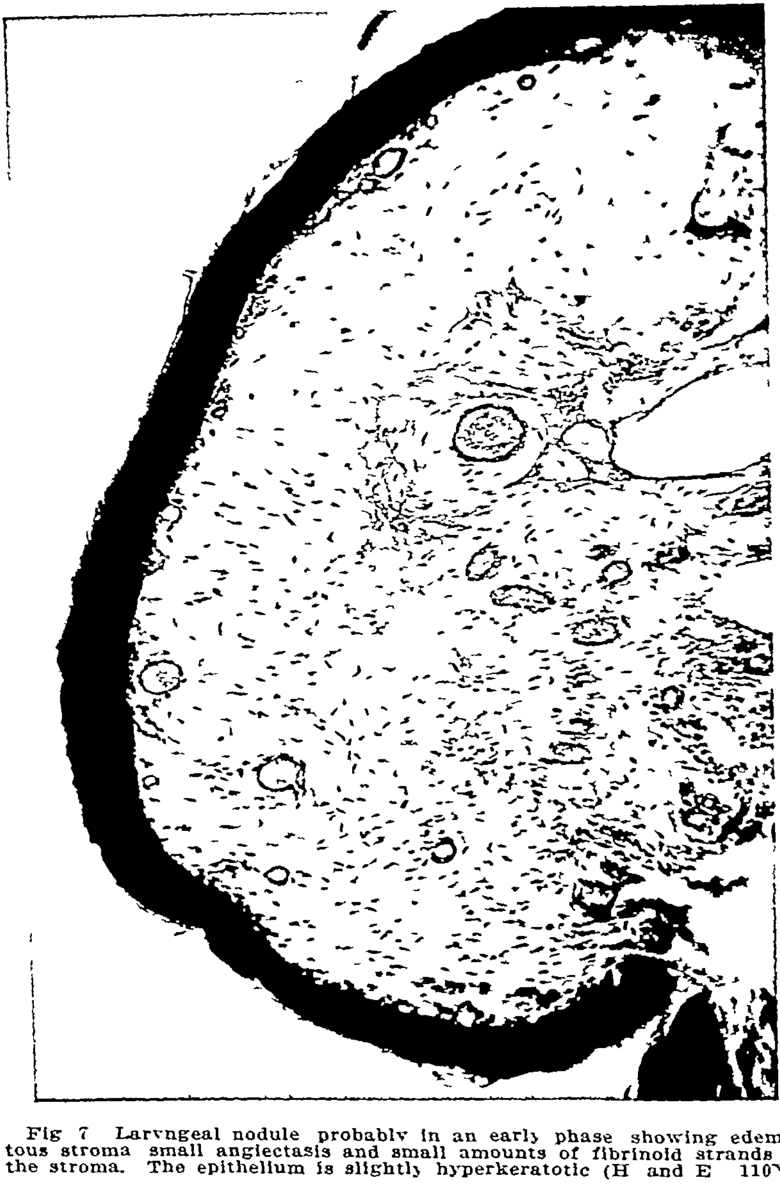

Fig 7 Laryngeal nodule probably in an early phase showing edematous stroma small angiectasis and small amounts of fibrinoid strands in the stroma. The epithelium is slightly hyperkeratotic (H and E 110X)

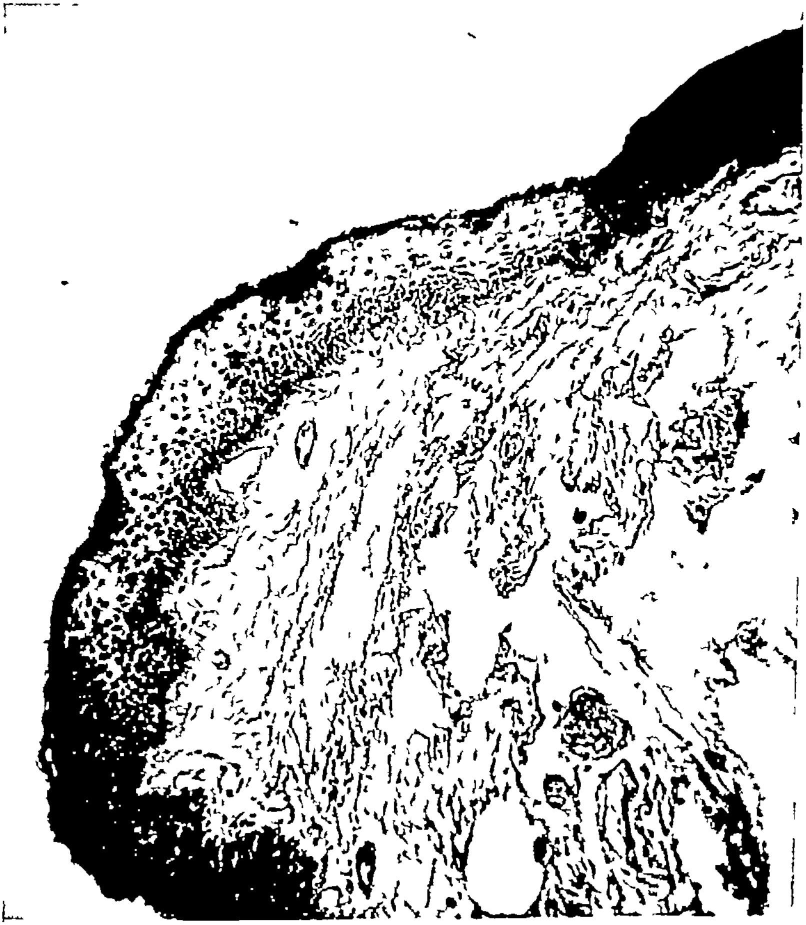

Fig 6 Laryngeal nodule with angiectasis myxoid stroma coarse fibrinoid strands in the stroma particularly about the dilated blood vessels or lymphatics and hyperkeratotic epithelium (H and E 110×)

juvenile and adult forms These are tumors of epithelial origin

EPITHELIAL CHANGES

This is a division which, in any table of classification, could receive a wide variety of cases In the first group examined, approximately 40 specimens were reported as showing some type of abnormal epithelial changes Upon

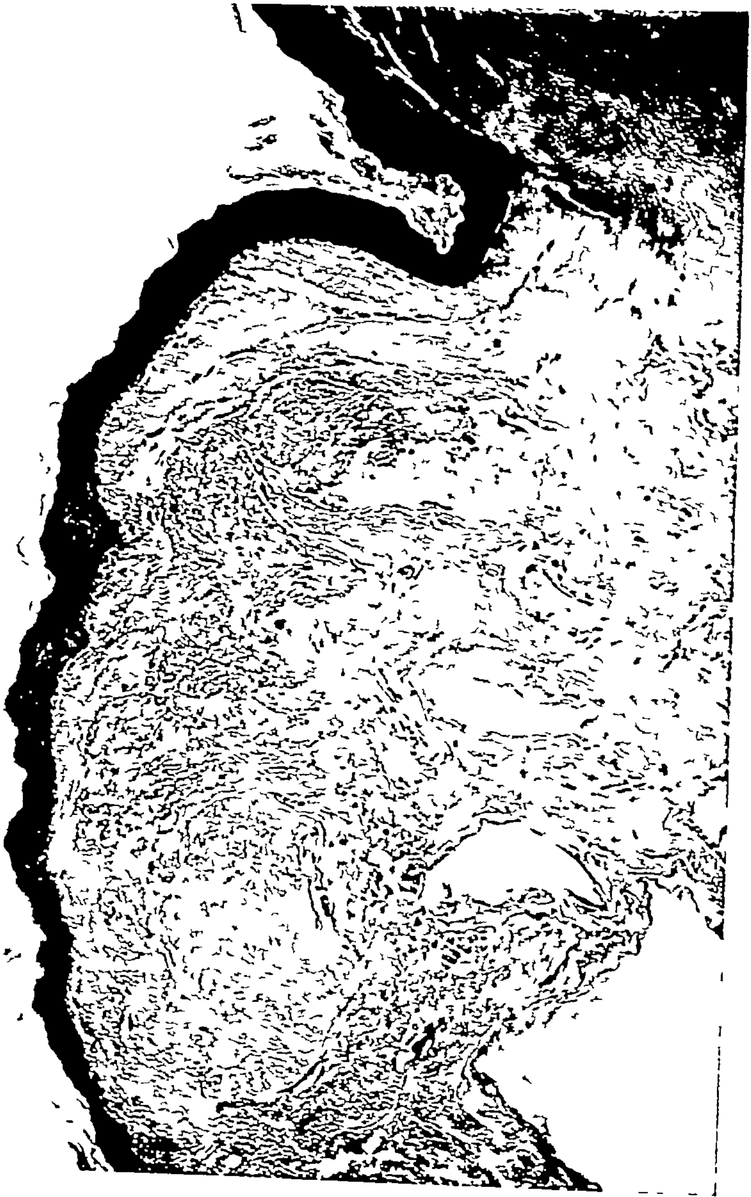

Fig 8 Laryngeal nodule probably in a late phase with extensive fibrinoid and fibrous transformation of the stroma and hyperkeratosis of the epithelium (H. and E 110X)

re-evaluation, the number, as will be noted, was reduced to 25

Hyperplasia, hyperkeratosis (hyperkeratinization) and dyskeratosis are not uncommon laryngeal conditions Many of the less severe cases undoubtedly never come to biopsy We do not believe that one sees the advanced dyskeratosis or leukoplakia of the vocal cord that one finds in the intraoral cavity Epithelial changes of the mucosa of the vocal cords deserve the most careful scrutiny, and material should be removed for histological examination without procrastination Such measures will eventually disclose an early carcinoma

The two lesions secondarily designated as carcinoma *in situ* were either erroneously diagnosed or the carcinoma was removed as an excisional biopsy, for prolonged follow-up examinations have revealed no subsequent malignant developments In the case of tissue diagnosed as frankly epidermoid carcinoma, we have not been so fortunate in our follow-up Although all efforts were exhausted in attempting to obtain further information about this patient, these were without success

CYSTS

The diagnosis of cyst was apparently not difficult, pathologically There was general unanimity of opinion in the examinations of the specimens

PYOGENIC GRANULOMATA

The granulomata, approximately 23 in number initially, after the revisional examination, became a group composed of only ten cases, the inflammatory category gaining therefrom

The appearance of these growths was that of a localized, nodular, and commonly polypoid mass of granulation tissue, containing many capillaries, in a stroma of young fibroblasts It is usually heavily infiltrated by histiocytes, and may contain an appreciable number of granular leukocytes The overlying epithelium is customarily intact and hyperplastic, sometimes to the point of pseudoepitheliomatous hyperplasia

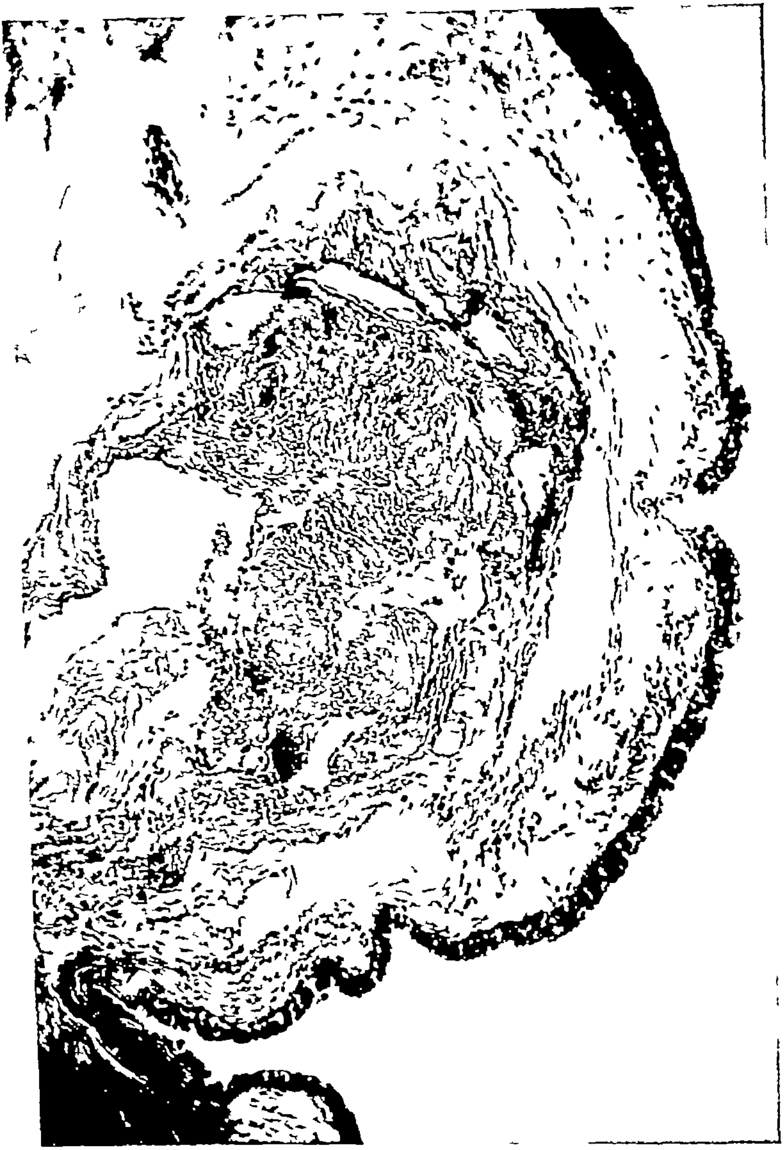

Fig 9 Laryngeal nodule with large fibrinoid mass resembling an organizing thrombus (H and E. 110X)

It differs from ordinary granulation tissue, which is frequently in an area of ulceration, showing superficial necrosis and intense, acute inflammation

MISCELLANEOUS GROUP

Of the original 300 sections, 15 were found to have been misplaced or misfiled, and could not be located for this study The second pathologist considered the tissue of nine specimens inadequate for diagnosis, and these were rejected for further consideration The corrected number of cases re-examined was 276, and it is gratifying that "normal mucosa" was reported in only three instances One true hemangioma was present The section of skin was obviously labeled improperly The case of lymphoid nodular infiltration has been followed for several years, and there has been no subsequent evidence of lymphoma or leukemia

COMMENTS AND SUMMARY

A consecutive series of 300 specimens of tissue removed from the vocal cords of the same number of patients were examined histologically by two or more pathologists The sections were collected over an eight-year period, ending May, 1957 Only benign lesions were analyzed, and no consideration was given to the oft-raised question as to whether benign overgrowths of subepithelial structures should be designated as "true tumors" or not No cases initially diagnosed as carcinoma were studied in this survey

The first analysis was carried out by pathologists who were genuinely interested, but not specifically, in laryngeal specimens The second examiner was one who showed particular interest in this type of tissue For various reasons, the second pathologist had the opportunity of reporting on only 285 sections rather than the 300 available to the initial group of examiners

The sex incidence indicated 68 3 per cent of the patients as males and 31 7 per cent females, with the highest age incidence being in the 41 to 50-year group

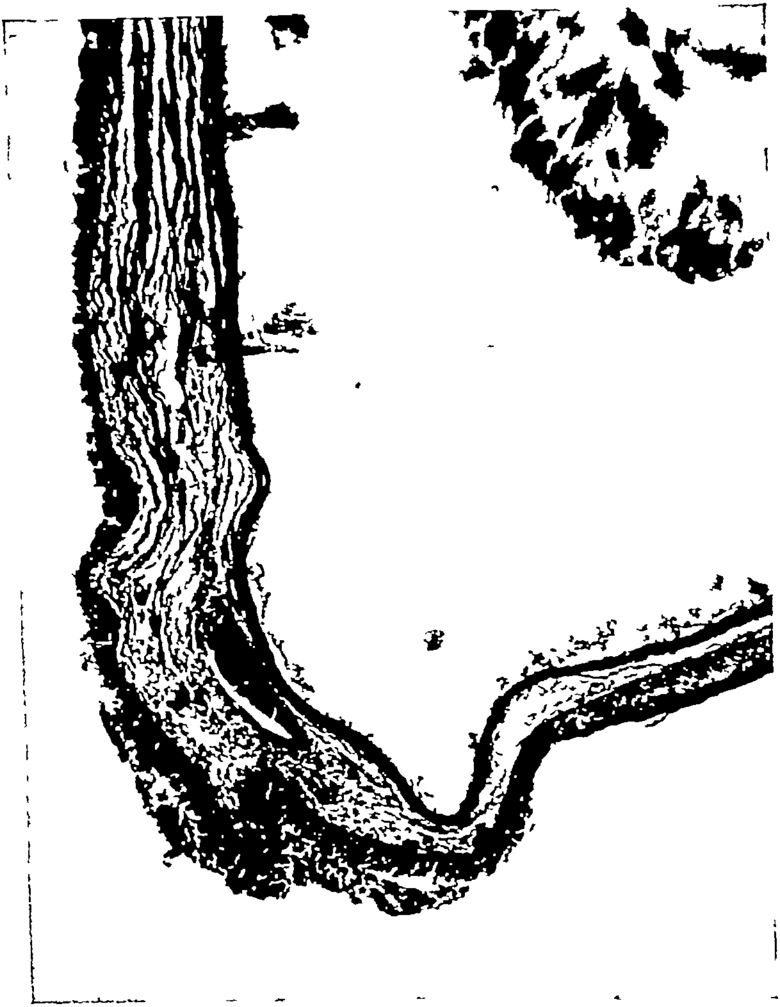

Fig 11 Laryngeal cyst lined by cuboidal or simple squamous epithelium (H. and E 110X)

upon the opinion of different pathologists Some have considered a laryngeal polyp as a stage in the development of a nodule, and vice versa, not two clinical entities The reason for this is apparent, as there are many variations in the histological appearances of these lesions, particularly in laryngeal nodules when degenerative changes have occurred That

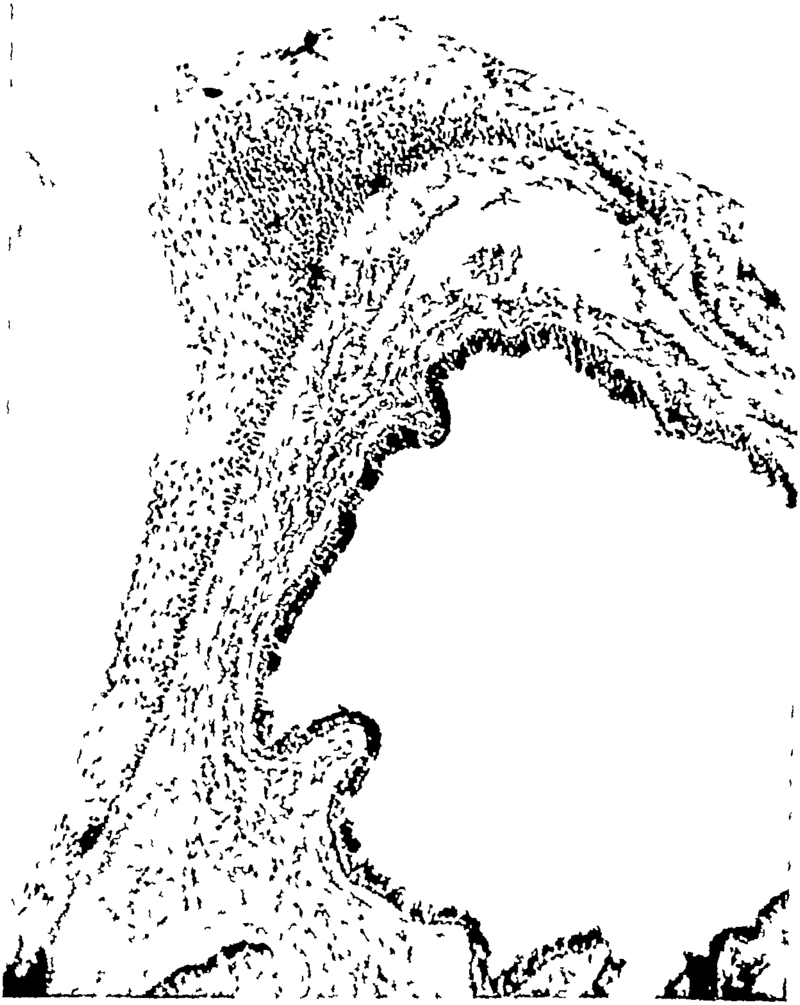

Fig 10 Laryngeal cyst lined by columnar epithelium The overlying squamous epithelium is slightly hyperkeratotic (H and E 110X)

From our own material and that available in the literature, there is obviously much confusion in the nomenclature and histological interpretation of benign specimens from the vocal cords This is especially true of lesions arising from the subepithelial connective tissue layers (Reinke's space), which have been designated as nodules or polyps, depending

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AMERICAN ACADEMY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY HOME STUDY COURSES

The 1958-1959 Home Study Courses in the basic sciences related to ophthalmology and otolaryngology, offered as a part of the educational program of the American Academy of Ophthalmology and Otolaryngology, will begin on September 1 and continue for a period of ten months Detailed information and application forms may be secured from Dr William L Benedict, the executive secretary-treasurer of the Academy, 15 Second Street, S W, Rochester, Minnesota Registrations should be completed before August 15 we can always histologically differentiate exactly between the two is certainly not clear It would seem possible that the laryngologists and pathologists interested in this subject could establish a certain criterion for distinguishing between the two, which could be used to dispel the confusion that exists in the identification of these benign vocal membranous changes

No definitive classification is attempted, because clinically it is difficult to do this, as there is so little difference in the appearance and conduct of many of the lesions Again, from our survey, we must conclude that this same difficulty is experienced by the pathologist In lieu of a classification, we have placed the results of our examinations in certain groups which will be helpful to us in clarifying the subject in the future

Certainly, one admonition is recommended, namely, "laryngologist, know your pathologist" It is obviously desirable that the laryngologist, in turn, supply the pathologist with more detailed information about the gross appearance and characteristics of the tissue to be examined

The accompanying photomicrographs illustrate some of the examples of the specimens described, and Table IV shows a comparison between the commoner lesions seen by the first pathologist with the revision in the diagnosis by the second

Finally, in summarizing, it appears that the vocal cord lesions which seem to be the most confusing to all are the laryngeal nodule, polyp, and possibly the papilloma Fundamentally, we consider the nodule as being an overgrowth of tissue containing an abnormal tunica propia, due to various degenerative changes, with an essentially normal surface epithelium The polyp is an overgrowth of tissue with an increase in quantity of a normal, or near normal, appearing tunica propia with no degenerative changes and an essentially normal epithelium These two lesions are of subepithelial origin The papilloma is a tumor containing a normal tunica propia, but an abnormally broad hyperplastic epithelial surface which may show other minor metaplastic changes

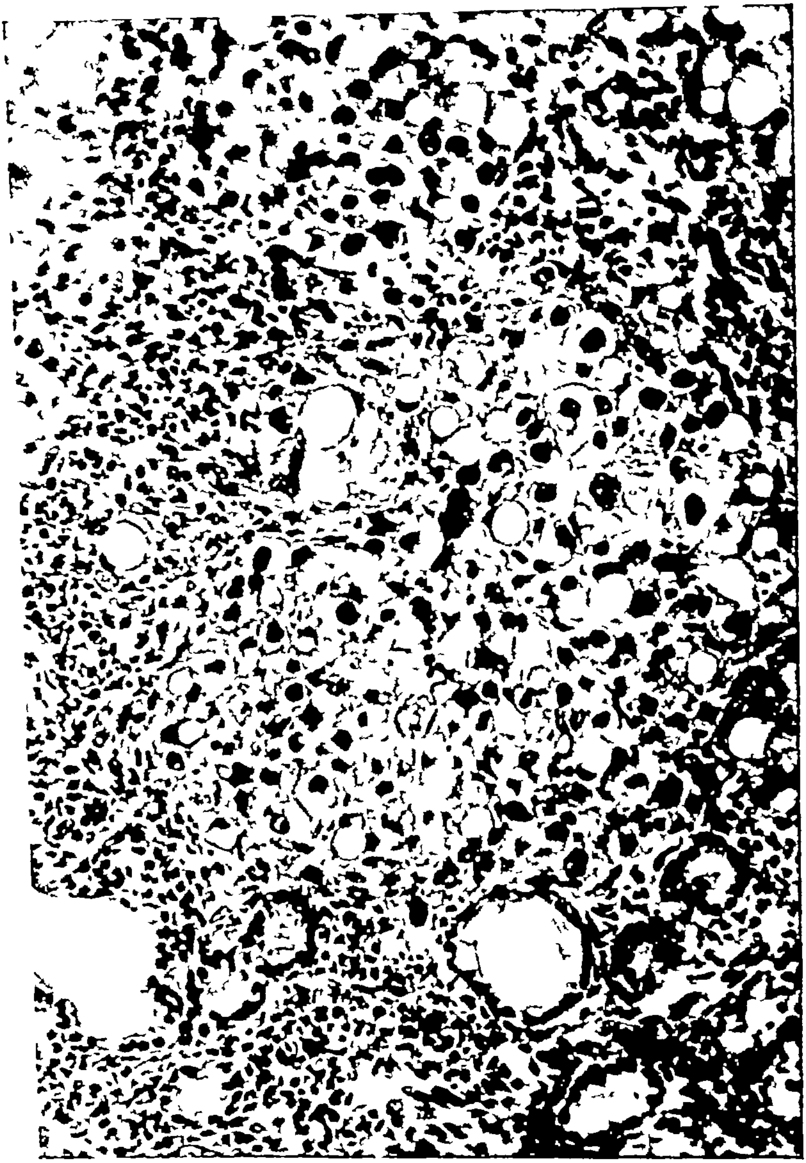

Fig 1 Medullary squamous cell carcinoma of Grade IV malignancy with extensive anaplasia and nuclear degeneration There were marked poikilocytosis and anisocytosis with hydropic degeneration of protoplasm The characteristic feature above all others was a very active lymphoid reaction (Reproduced by permission of Arch of Otolaryngology)

CANCER OF THE LARYNX

Report of an Advanced Case Surviving 22 Years

ARTHUR E HAMMOND, M D,

Detroit, Mich

In a previous article* the author reported on a series of 15 cases of carcinoma of the larynx which were analyzed from the point of view of age and sex incidence, etiology, classification, symptom complex, histologic grading and especially the various forms of surgical procedures It was stated at that time that radiation therapy—besides being the method of choice in extrinsic carcinoma of the larynx—may prove of definite value in some advanced intrinsic carcinomas of the larynx having a high index of malignancy with glandular metastases

The present brief communication is a report of Case II of that series, which in 1935 was referred for radiation therapy because of the advanced clinical stage of the lesion, and particularly since the histopathologic examination indicated a Grade IV index of malignancy The patient has now survived, enjoying good health, for a period of 22 years

REPORT OF A CASE

The patient an adult white male forty seven years old, was seen at the office on September 20, 1935 complaining of difficult breathing The history was that of progressive hoarseness over a period of five months with recent painful swallowing, difficult breathing and a weight loss of 12 pounds

Indirect laryngoscopic examination revealed a large fungating tumor mass apparently arising from the right vocal cord which was fixed There was one large soft, freely movable lymph node in the right supraglottic area and two smaller soft and freely movable lymph nodes in the left supraglottic area

The patient was admitted to Harper Hospital and direct laryngoscopy was performed on September 21 1935 under local anesthesia The epiglottis was edematous A large bleeding fungating mass covered the right vocal cord with some involvement of the left vocal cord The right vocal cord was fixed Biopsy was taken from both vocal cords

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*Archives of Otolaryngology January 1942 Vol 35 pp 1-29

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On September 22 1935 a low tracheotomy was performed under local anesthesia and because of the extensive nature of the lesion the patient was referred for radiation therapy

Between Sptember 24 1935 and March 10 1936 three series of super voltage Roentgen therapy were given with 500 kv (constant) 7 mm. Cu filter corresponding to a half value layer of 9 mm. Cu. The fractionated protracted technique was used the total cumulated dose on the pathologic areas being 7 000 r

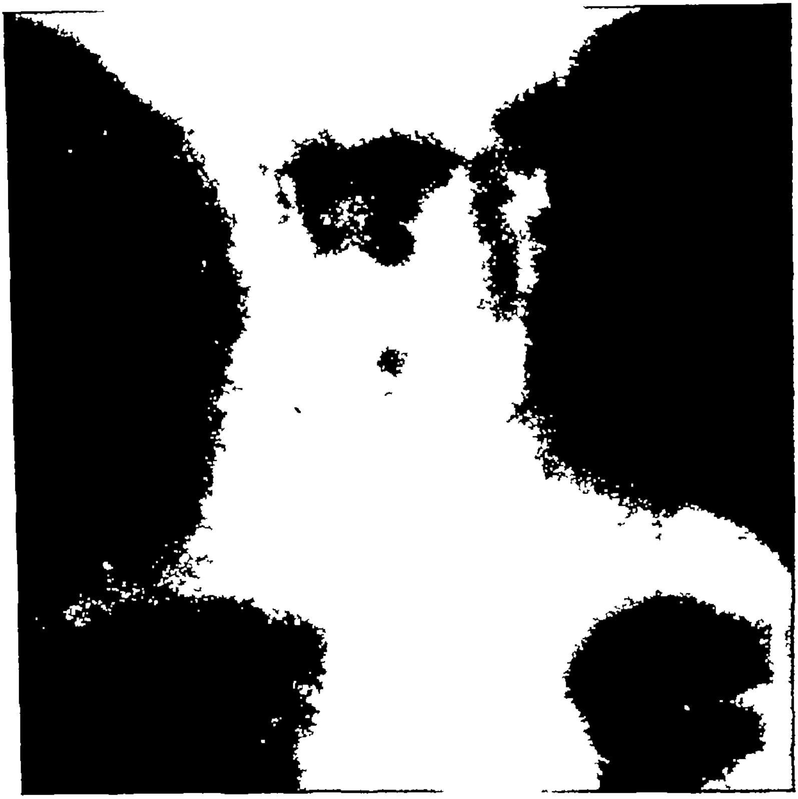

Fig 3 Laminagram in the coronal plane shows the tracheotomy tube in place There is a marked distortion of the glottic folds on the two sides particularly on the left, but with the patient phonating the letter e a fairly good apposition of the vocal cords was obtained and the Morgagni space appeared fairly normal in contour

November 17 1935 Tracheotomy tube was removed and the opening closed spontaneously

There was a satisfactory response to the radiation therapy and subsequent periodic follow up examinations gave the following findings

September 5 1940 The patient has gained five pounds in weight. He

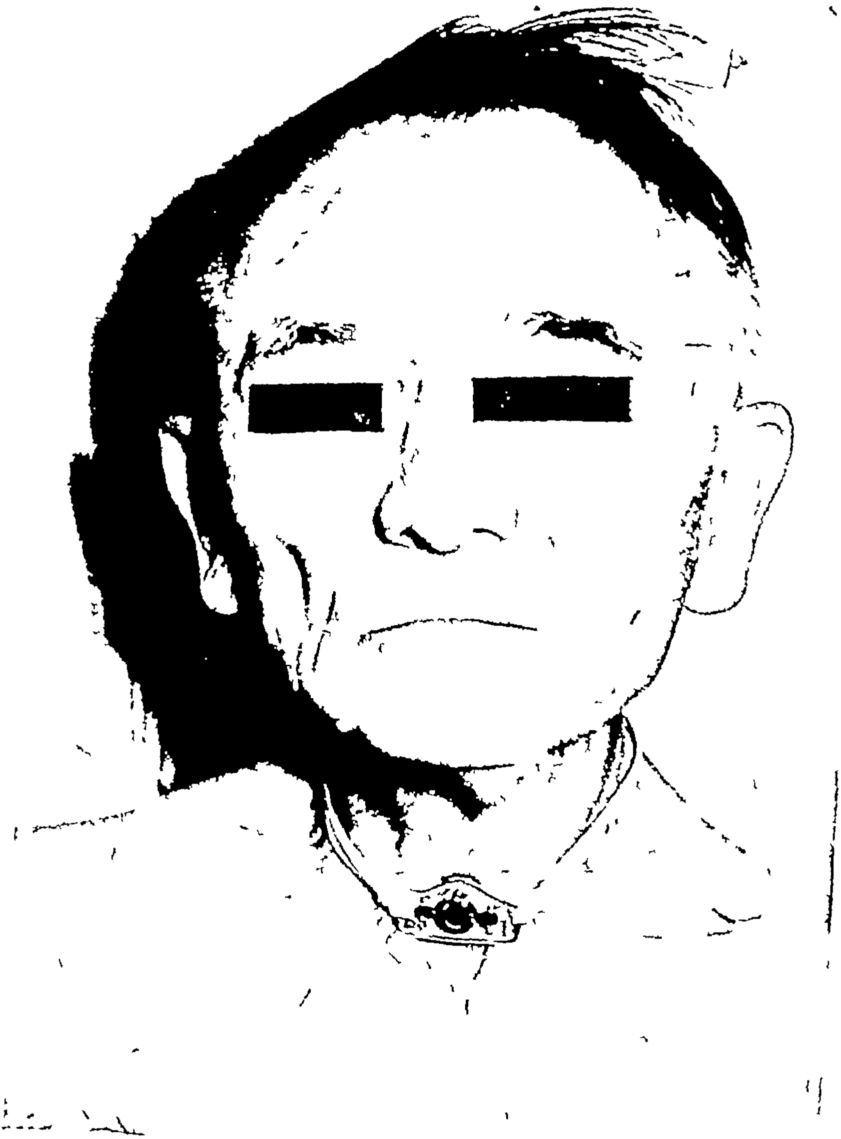

Fig 2 Photograph showing appearance of neck 22 years later with the tracheotomy tube *in situ*

The histopathologic report was that of medullary squamous cell carcinoma Grade IV with extensive anaplasia and nuclear degeneration There were marked poikilocytosis and anisocytosis with hydropic degeneration of protoplasm The characteristic feature above all others was a very active lymphoid reaction (see Fig 1)

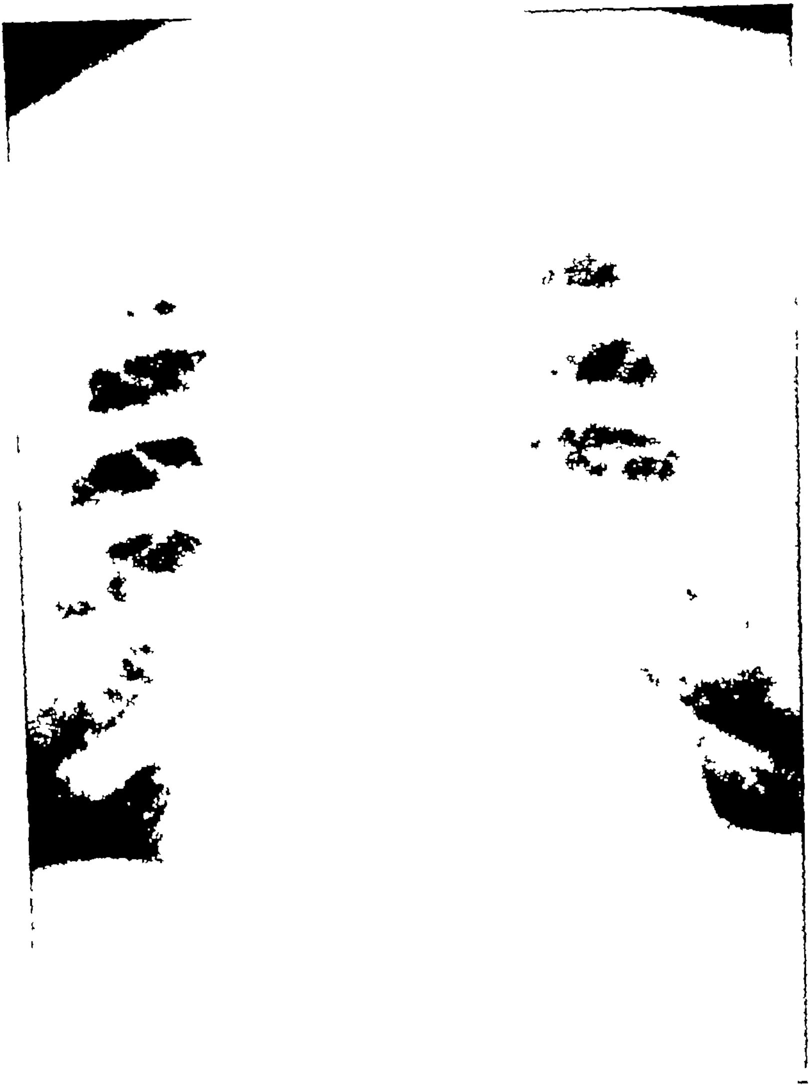

Fig 5 Posteroanterior roentgenogram of the chest reveals slight generalized pulmonary edema with some prominence of the bronchovascular markings

was in good general condition There were no palpable lymph nodes of the neck and no hoarseness Indirect laryngoscopic examination showed a normally functioning larynx There was no evidence of any carcinoma and the vocal cords were freely movable

October 30 1944 The patient has gained an additional three pounds

Fig 4 Lateral roentgenogram of the neck with soft tissue exposure and barium swallow shows no abnormality of the esophagus

A TECHNIQUE OF TYMPANOPLASTY (TYMPANOMALLEOLAR STAPEDIOPEXY) *

HOUSTON L BELL, M D ,

Roanoke, Va

In a recent article, "Technique of Tympanoplasty", published in the *Archives of Otolaryngology,* the author reported on two cases of tympanomalleolar stapediopexy It was noted that where possible, if the head of the malleus was preserved and rotated in such a manner that it were allowed to come in contact with the capitulum of the stapes, it not only served as a sound conducting structure, but also produced a tenting effect on the drum or new graft, thus preserving a greater vibratory capacity of the drum

Since the vibratory capacity of the tympanic membrane, or new graft, plays the major role in the transformation of sound pressure from drum to oval window,[1-17] it is mandatory to maintain as much vibratory area as possible in the tympanoplasty procedure Much work has been recorded in the European literature showing attempts to improve vibrating surface of new grafts In a few cases Wullstein attempted to line the hypotympanum and tubotympanum with ocular conjunctiva or amniotic membrane This would seem to make for a more complicated procedure in an already complex operation House has described the use of vinyl prostheses placed in the hypotympanum and extending through the Eustachian tube

In my own series of 100 cases of tympanoplasty, surveyed as of July, 1956, all Type III tympanoplasties or tympano stapediopexies were carried out in the conventional manner, namely

1 Tympano atticotomy and removal of diseased tissue from the antrum and removal of surgical bridge

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*Read at the meeting of the Southern Section American Laryngological Rhinological and Otological Society Inc Memphis Tenn Jan 25 1958

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weighing 144 pounds, and he continued to feel well There was no evidence of cervical lymph adenopathy Laryngoscopic examination was negative for any pathology

July 11 1945 Weight 144 pounds Laryngoscopic examination negative Neck normal

February 21 1948 Weight 148 pounds General condition excellent Larynx and neck normal

October 26, 1956 Patient reported to the office with a history of recent spells of difficult breathing There were no other complaints Indirect laryngoscopic examination revealed abductor paralysis of both vocal cords

On October 27, 1956, he was re-admitted to Harper Hospital for a tracheotomy Examination at this time revealed a well developed and well preserved elderly white male who had obvious laryngeal stridor and hoarseness His distress was not acute and the stridor was more marked with expiration The general physical examination was negative, and the laboratory data were all within normal limits There was no evident induration of the structures of the neck and no enlargement of the cervical lymph nodes

On October 28, 1956, direct laryngoscopy and tracheotomy were performed The larynx was negative for any swelling, ulceration or tumor masses There was bilateral abductor paralysis of the vocal cords of indeterminate cause

The patient was discharged to his home on November 5 1956

On February 1, 1957 patient was re-examined There was a normal appearance of the neck externally except that a tracheotomy tube was *in situ* (see Fig 2) Laminagraphic examination of the neck was made in the coronal plane (see Fig 3), which revealed the following findings A tracheotomy tube was in place but did not interfere with visualization of the glottic area There was a marked distortion of the glottic folds on the two sides, particularly on the left, but with the patient phonating the letter 'e a fairly good apposition of the vocal cords was obtained and the Morgagni space appeared fairly normal in contour Lateral roentgenograms of the neck with soft tissue exposure likewise showed the tracheotomy tube in place but no other findings Barium swallow demonstrated no definite esophageal abnormality (see Fig 4) Postero-anterior roentgenograms of the chest disclosed slight generalized pulmonary emphysema with consequent prominence of bronchovascular markings throughout the lung fields There was an old pleural reaction in the left costophrenic sulcus region but no active lung disease No parenchymal or pleural metastases were seen The ribs, insofar as visualized appeared intact (see Fig 5)

SUMMARY

A case of advanced medullary squamous cell carcinoma of both vocal cords, taken from a series of 15 cases published formerly, is reported briefly The patient was treated with supervoltage Roentgen therapy and has now survived for a period of 22 years

Harper Hospital

has its own natural simple stratified squamous inner lining, and good results are obtained in the majority of cases, again where there is only a marginal rim of drum membrane present and it must be preserved for attachment of the new graft to the denuded drum remnant. It not only serves as support for the new drum but also provides excellent blood supply for its preservation Where the ear is dry and the mucosal lining of the tympanic cavity is thin and atrophic, good results will be obtained with tympano stapediopexy but in a smaller percentage of cases, because in an effort to contact the graft to the stapes adhesions and a lowered vibratory area results If the mucosal lining of the cavum tympanum is hyperplastic and cystic it must be stripped away, along with carious deposits in the hypotympanum and tubotympanum, and the problem of maintaining a mucosal-lined cavity with a vibrating new drum contacting the stapes becomes increasingly difficult If one errs in preserving the mucosa, he will many times end up with a persistently discharging ear, a slight or no hearing gain and a dissatisfied patient

In the review of post operative results, it was noted that the larger the drum defect replaced with free graft contacting the stapes, even though all other ideal conditions in the tympanic cavity prevailed for optimum results, the less consistent were good hearing results Many times, the three-week audiogram would show a good hearing gain, well above the 30 db level, only to be followed by a gradual recession of the pure tone curve at or below the level of adequacy (30 db level) This loss is unquestionably due to fibrosis of the raw inner surface of the new graft to the medial wall of the tympanum, resulting in reduction of vibratory capacity, thus lowering the sound conduction ratio It becomes essential then to preserve as much vibratory area as possible, and to do this one should attempt to elevate the flap from the tympanic wall rather than merely to adhere it to the bony prominence of the cochlear promontory Realizing that the promontory is necessary many times as a source of blood supply for the new graft, elevation of the graft is still not only a prerequisite but also a definite advantage as far as sound conduction ratio is concerned

2 Gross and microscopic examination of the ossicular chain for cholesteatoma or disruption of ossicular chain If the otologist is assured of absence of intra-tympanic pathology, such as is many times the case in so-called primary cholesteatoma of pars flaccida, and if the stapes is mobile along with intact ossicular chain, the pedicle graft is used, the edges of the perforation are approximated and the patient is assured of reasonably good hearing at least above the 30 db level Some observers have stated that many times the hearing will recede in these cases due to

- *a* eventual dislocation of the incus from the head of the stapes
- *b* adhesions from the pedicle hampering the movement of the ossicular chain

I believe that dislocation of the incus is an operative hazard, and secondly, adhesions may be avoided if one preserves a high dome on the facial ridge, and if one preserves the anterior and posterior spines

3 If there is bony ankylosis, or a dehiscence in the narrow portion of the long process of the incus constituting a break in the ossicular chain, one then elects to do a tympano stapediopexy The anterior and posterior spines are removed, and the facial ridge is lowered as far as possible, almost to the facial nerve itself The tympanic membrane is mobilized posteriorly, escharred on its inner surface and tucked into the niche of the oval window contacting the head of the stapes Many times the capitulum projects to the level of the lowered facial ridge, and contact is no problem

Good results are obtained with tympano stapediopexy in those ears with perforation of the pars flaccida and primary cholesteatoma, because as a rule the mucosal lining of the cavum tympanum is intact and the hypotympanum and tubotympanum are not involved Likewise, good results are obtained where there are small marginal perforations of the pars tensa, providing one can preserve the mucosal lining of the tympanic cavity and the round window is demonstrated to be patent In both of these cases the tympanic membrane chain, assuming mobile stapes and normal round window membrane with patent niches are present

2 Tympano malleolar stapediopexy, or stapes to malleus to drum procedures, are employed where large marginal drum defects (30 per cent or more) are present, and stripping of cystic hyperplastic mucosa from the tympanum, hypotympanum, and tubotympanum is necessary

3 It is felt that preservation of the malleus rotated and applied to the head of the stapes produces a tenting effect and better vibratory capacity of a new drum more free of adhesions to the medial tympanic wall surrounding the stapes

4 The observation is made of good hearing improvement to the satisfactory level in a secondary fenestration of a radical cavity in which there was no gross evidence of a mucosa-lined cavity from the tubotympanum to the patent round window, thus indicating that possibly in some cases only an air bubble over a functioning round window membrane is necessary for adequate intra-labyrinthine phase interval

5 It is, therefore, theorized that in those patients with atrophic or absent mucosal lining in the vicinity of the round window area, if there is satisfactory tenting of a new graft, produced by the head of the malleus, assuming a functioning round window membrane exists, it is possible to achieve a satisfactory hearing gain, even though there is no gross evidence of mucosally lined cavity demonstrated by mobility of the new drum.

AMERICAN BOARD OF OTOLARYNGOLOGY

The American Board of Otolaryngology will conduct only one examination in 1958, and this will be October 6-9, 1958, in Chicago, Illinois, at the Palmer House

For further information address Dr Dean M Lierle, Secy-Treas , University Hospital, Iowa City, Iowa

In the last 70 tympanoplasties, operated on since July, 1956, I, therefore, have concentrated on preserving the head of the malleus where possible, in all cases in which extensive intratympanic surgery was performed, and large free graft was employed, rotating it over the head of the moveable stapes and attaching the free graft to the denuded drum remnant, the head of the malleus and the facial ridge posteriorly This creates a tenting support of the new drum and provides a greater vibrating surface at the oval window, as well as a shielding of the round window Applying this principle to those cases in which it was necessary to employ radical removal of diseased hyperplastic mucosa in the entire tympanic cavity and obtaining a few good hearing improvements, I then employed the procedure in a few patients with pars flaccida lesions with uniformly good results At the present time, where possible, the head of the malleus is preserved in all cases with large marginal defects and extensive disease of the tympanic cavity and where the stapes is deeply set, and hearing is in my opinion better than in stapes to drum procedures, due most likely to increased vibratory capacity

It was noted that in one patient in whom a secondary fenestration procedure was performed on a dry radical mastoid cavity in which there was *no gross* evidence of mucosa-lined cavum tympanum, the patient received an excellent hearing gain to the practical level This indicated that a mucosa-lined cavity extending from the round window to the Eustachian tube may not be necessary in all cases, but merely an air bubble over the round window would suffice for preservation of intra-labyrinthine phase relationship, providing the round window were patent and the stapes mobile This would be especially true providing the mucosa were atrophic or absent

CONCLUSIONS

1 Tympano stapediopexy, or stapes to drum procedures, are employed where the membranous lining of the cavum tympanum is intact and the simple squamous lining of the tympanic membrane is normal, such as in a perforation of pars flaccida, cholesteatoma and ankylosed or broken ossicular the reconstructive operation in one stage Multiple operations tend to create more fibrosis and adhesion formation

Five types of tympanoplasty (Wullstein[2]) have been advised to accommodate these various pathological changes

Type I Plastic closure of an eardrum perforation

Type II Preservation of the ossicular chain with large grafts covering the perforated drum and the bridge and/or ossicles

Type III Removal of the malleus, incus, and bridge, and the placing of a graft onto the drum remnants and head of the stapes

Type IV Removal of remnant of ossicles and bridge in cases without a stapes with a graft applied to the promontory or into the oval window and sealing off the hypotympanum, round window and Eustachian tube from the external ear

Type V Same as Type IV, with the addition of fenestration into the horizontal semicircular canal

A comparison has been obtained between 76 tympanoplasties performed in the first ten months of 1957, with 75 conservative or modified radical mastoidectomies performed in previous years, as to results achieved Against these two groups we have also tabulated a group of 50 radical mastoidectomies

In demonstrating the results obtained in the tympanoplasties, one must consider, first of all, that these are the earliest cases attempted in this type of surgery, and second, these cases are so recent that final hearing results may be somewhat better than we demonstrate at present, furthermore, these cases are not selected, but rather represent consecutive cases that presented themselves and were operated upon, using various ones of the five types of tympanoplastic procedures described by Wullstein [2]

The method of charting the comparisons is as follows The hearing before surgery was averaged for the frequencies of 500, 1000, and 2000, and plotted on a vertical line Gains in

RESULTS IN TYMPANOPLASTY

A Comparative Study of 76 Tympanoplasties, Contrasted with Modified Radical, and Radical Mastoidectomies *†

BRUCE PROCTOR, M.D.,

Detroit, Mich.

Tympanoplasty may be defined as the combination of surgery for eradication of chronic ear inflammation and surgical reconstruction of the sound conducting and sound protecting mechanism. Frenckner[1] reported recently: "Tympanoplasty . . . is now embraced with greater interest in a number of different clinics in Europe. In my opinion, this would seem to have become one of the broadest and most important fields of operation within otology during the recent decades. In the United States, on the other hand, this operation is viewed with considerably more skepticism, and has not yet aroused the proper interest." My comment here would be, that many American otologists are now working in this field, and it is hoped that before long we will contribute to the progress of this concept, pioneered by European otologists.

From what we have learned in tympanoplasty, it is apparent that early operation of chronic ear inflammation is advisable, both from a functional and also from the microsurgical and anatomical point of view. When it is obvious that an inflammatory disease in the middle ear is irreversible by conservative measures, and will progress with functional deterioration, it is imperative that surgery be performed, even though an ideal result can not be promised. The earlier that this is done, the less destructive will be the pathological changes in the epitympanum, ossicular chain, drumhead, Eustachian tube, hypotympanum, annular ligament, and round window niche and membrane. Every attempt should be made to perform

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*Read at the meeting of the Middle Section American Laryngological, Rhinological and Otological Society, Chicago, Ill., Jan. 13, 1958.

†Department of Otolaryngology, Wayne State University.

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taneously with a false drum adherent to the promontory and protecting the round window Toward the end of this series were recorded a group with profound losses in hearing, due to serous labyrinthitis complicating fistulas in the horizontal canal These cases submitted to radical mastoidectomy because of labyrinthine complications

A group of 75 consecutive conservative or modified radical mastoidectomies were then reviewed, (see Figs 3, 4, 5, 9)

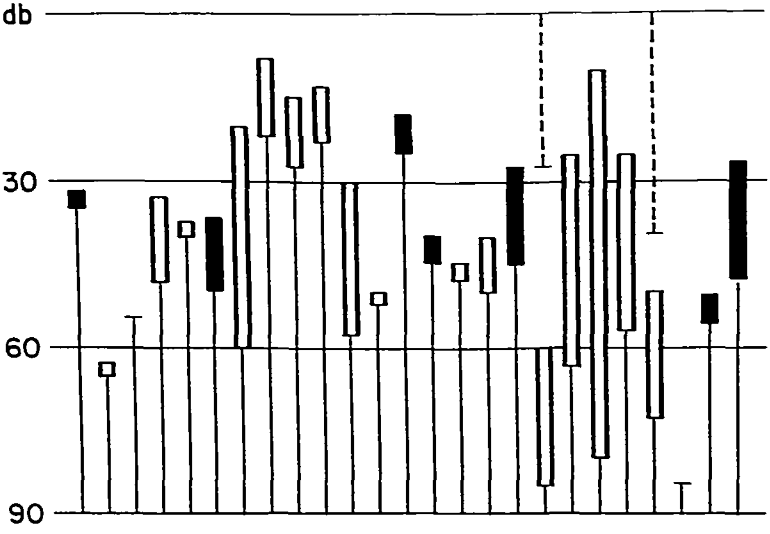

Fig 2 Radical Mastoidectomy

Many of these cases were undoubtedly candidates for radical exenteration, but because active pathology appeared to be confined to the attic and/or antrum, the middle ear was often not disturbed, hoping that some hearing would be restored In almost every case the bridge was removed In all cases the ossicles or remnants of ossicles were not removed The drum was not elevated or disturbed in any way When feasible a portion of the membranous posterior canal wall was left attached to the drum and swung on a pedicle to cover the ossicles Failure to gain hearing if coupled with suppuration, was followed by radical revision In 17 of the 75 cases, hear-

hearing are indicated on the vertical lines by the shaded bars, and losses by open bars No change is indicated by a short horizontal line Bone conduction losses are indicated by the dotted lines dropped from the top of the charts A bar connecting two vertical columns below the base indicates the two ears in one patient If the conductive loss is greater than 30 db for the main area of speech, the result is regarded as unsatisfactory, even though the operation produced a definite increase in the hearing

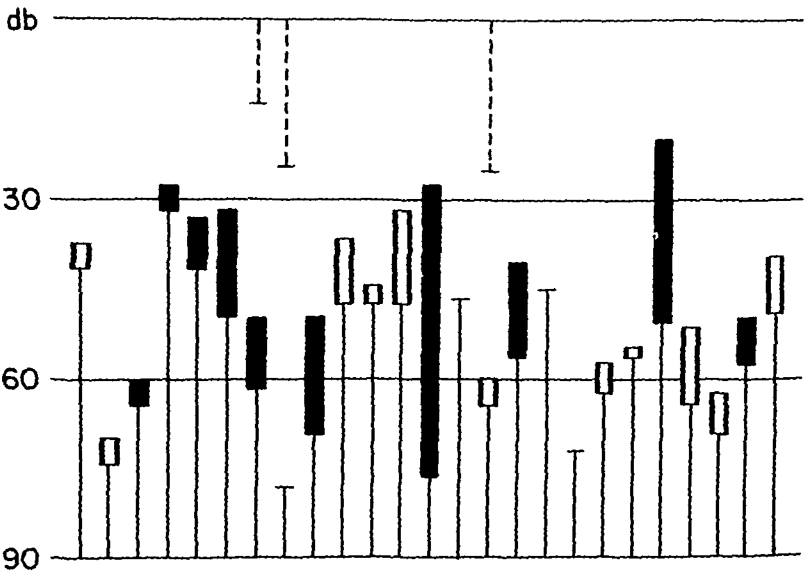

Fig 1 Radical Mastoidectomy

Before considering the conservative radical mastoidectomy group, we shall review the results obtained in the radical mastoidectomies with respect to hearing gain or loss This will give us some sort of base line to judge the effectiveness of the conservative radical ear surgery group In the group of 50 radical mastoidectomies tabulated (see Figs 1, 2), a total of 17 showed some gain in hearing, but only six improved over the 30 db level A total of 27 sustained further loss in hearing, and six were unchanged Two cases with a marked gain in hearing, surpassing the 30 db level, had healed sponis attributed to a perforation in the graft and to the formation of adhesions in the tympanum

Preservation of the ossicular chain with large grafts covering the perforated drum and the bridge and/or ossicles—Type II tympanoplasty (see Figs 6, 9) was performed in 23 cases In five cases gains to above the 30 db line were obtained In seven cases further hearing gains above this line were recorded In four cases some hearing loss occurred, but remained at or above the 30 db line In seven the 30 db line was not reached Seventy per cent of these cases had hearing above 30 db, and of these 35 per cent had hearing above a 15 db level Wullstein[2] considers the 15 db line a satisfactory level in Types II and III tympanoplasty These results compare favorably with those reported in this same manner by Wullstein[4] The results are surprisingly similar to those obtained with the modified radical mastoidectomy in 75 cases (see Fig 9) Jongkees[3] reoperated nine Type II tympanoplasties and attributed failures originally to the following Leaving ossicles with small defects, hoping that they would heal,

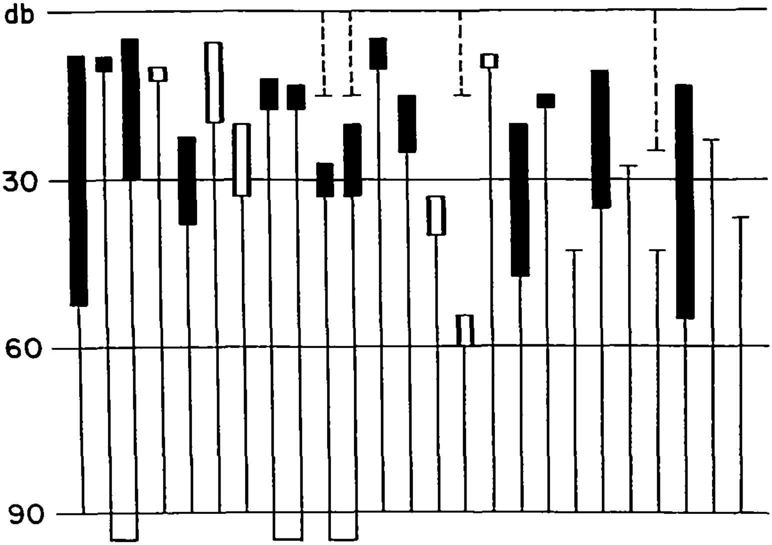

Fig 4 Modified Radical Mastoidectomy

ing was brought up to or surpassed the 30 db level In 32 cases, preoperative hearing losses of less than 30 db was maintained above that level Thus a total of 49 cases (65 per cent) benefited audiologically by conservative radical mastoidectomy as contrasted with only 12 per cent in the radical group Only five cases with preoperative hearing loss of less than 30 db dropped below this level

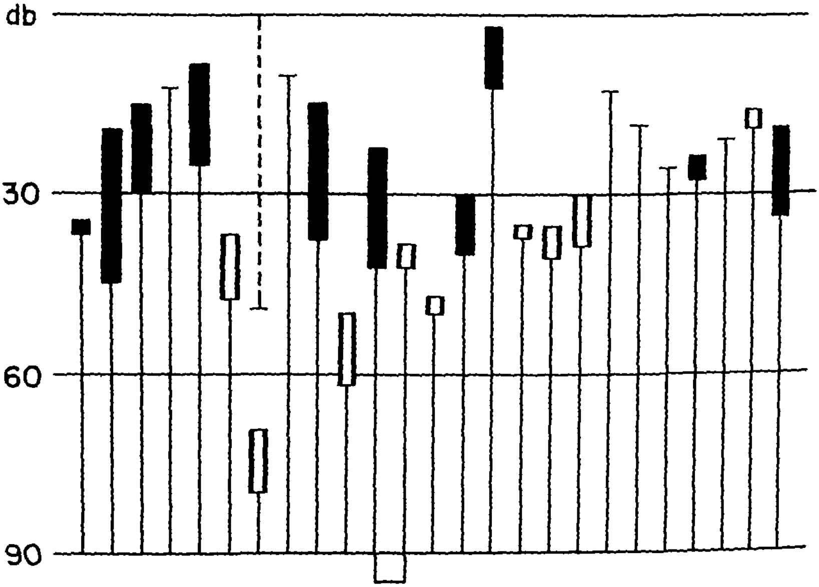

Fig 3 Modified Radical Mastoidectomy

In the first ten months of 1957 a total of 76 tympanoplasties were performed and their results compiled, even though many of them have not entirely healed It must be remembered that a survey of this type does not give an accurate picture of the benefits of this surgery For example, a cholesteatoma uniting disrupted ossicles may be responsible for relatively good hearing which drops considerably with the sole removal of the cholesteatoma Zollner[3] states that the starting point of rehabilitation should be reckoned at the lower level

Plastic closure of an eardrum perforation—Type I tympanoplasty (see Fig 6) was attempted in only four cases, with satisfactory results in three The failure in the fourth case

The relatively poor results in Type III, as contrasted to Type II, can be explained by the more extensive destruction of middle ear structures, and particularly the mucosal lining Destruction of mucosa by the inflammatory disease process, combined with a more complete removal of the bridge, predisposes to more extensive postoperative adhesion formation, particularly about the stapes, also, often very little, if any, is left of the eardrum, and the manubrium of the malleus is removed, so that the newly created eardrum is audiologically less effective than the normal drumhead Among nine failures reported by Jongkees[5] in Type III, the following factors were found responsible The arch of the stapes had been broken, residual inflammation had continued to destroy the originally intact stapes, too stiff or calcified stapedius tendon which prevented vibration of the stapes, non-adherence of the drum or graft to the head of the stapes, and adhesion of the drum to the promontory, due to too thick a graft, or insufficient post-operative inflation of the Eustachian tube

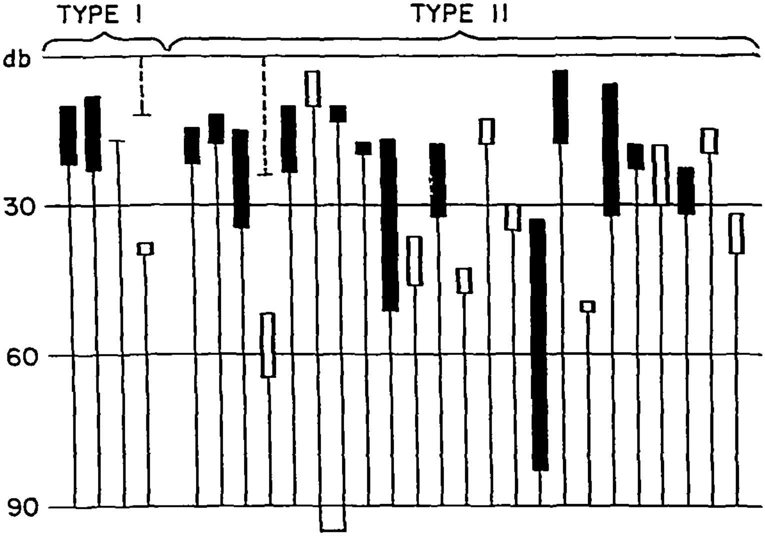

Fig 6 Tympanoplasty Types I and II

When the stapes is destroyed the latter cannot be used for its columellar (sound transmission) effect One might overlooking a disrupted ossicle, attempting to bring mutilated ossicles into contact with one another, insufficient removal of disease from middle ear or attic, covering active pathology with a skin graft, and granulation or cholesteatoma had reformed, and inadvertently overlooking a dislocation of the incus At reoperation the middle ear was cleaned, the incus and head of the malleus removed and the drum placed on the head of the stapes

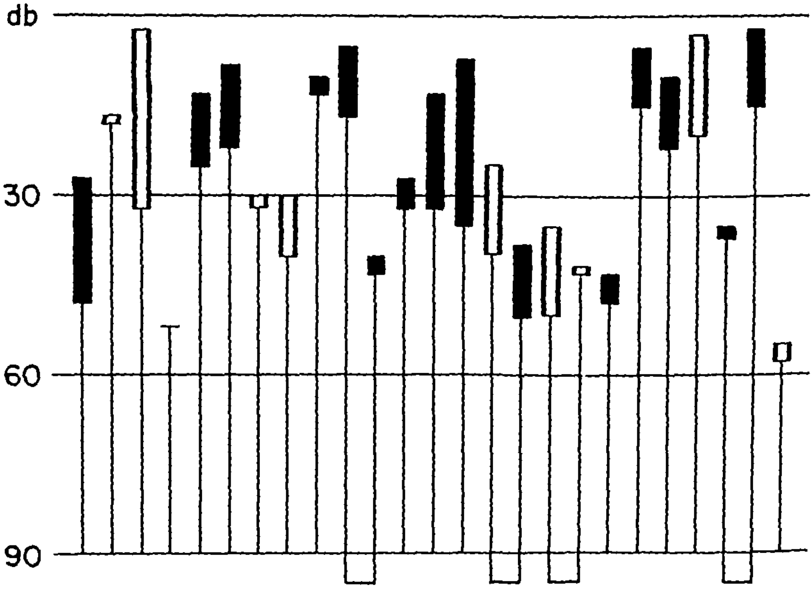

Fig 5 Modified Radical Mastoidectomy

Removal of the malleus and incus and the placing of a graft onto the drum remnants and head of the stapes—Type III tympanoplasty (see Figs 7, 9) was performed in 26 cases Hearing was improved in 20 cases, decreased in four cases, and remained unchanged in two cases In 12 cases the 30 db line was reached, and in five of these the 15 db line was reached In three cases hearing was maintained above the 30 db level, and one remained above 15 db The results reported by Wullstein[4] are better, in that 17 per cent of his patients reached the 15-30 db level This gap could probably be narrowed in time by improvement in skill and judgment panoplasty This has been attributed to the relatively thick, relaxed graft which seals off the small tympanum, offering excessive sound protection to the round window while the stapes footplate remains free Failures in 11 cases of Type IV tympanoplasty were revised by Jongkees[5] and were attributed to Closure of the oval window by tough connective tissue, the skin graft had not healed onto the oval window membrane or stapes footplate, a mass of tissue had formed

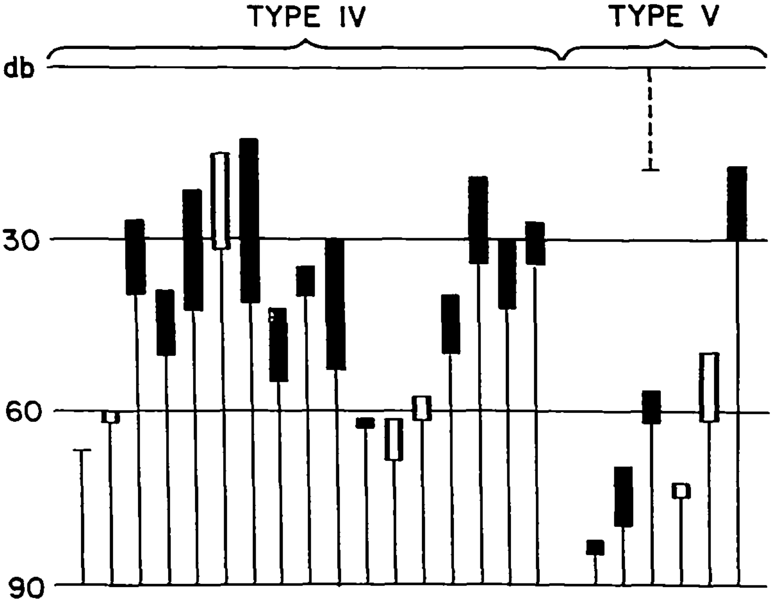

Fig 8 Tympanoplasty Types IV and V

in between the flap and the membrane of the oval window, or that the flap was too firmly fixed to the promontory

When the stapes footplate is fixed by new bone formation or dense adhesions so that it cannot be mobilized, one must consider then a fenestration into the horizontal semicircular canal with a graft again placed to seal off the round window, hypotympanum and Eustachian tube from the external ear—Type V tympanoplasty (see Fig 8) Six cases were attempted in this fashion The first five were old radical be able to use the transposition of a portion of the malleus or the incus to obtain a substitution columellar effect, (Miodonski,[6] Hall and Rytzner[7]), but often that is not possible, so that the choice is to create sound protection for the round window with a graft applied to the promontory, and if necessary into the oval window niche with sealing off of the hypotympanum

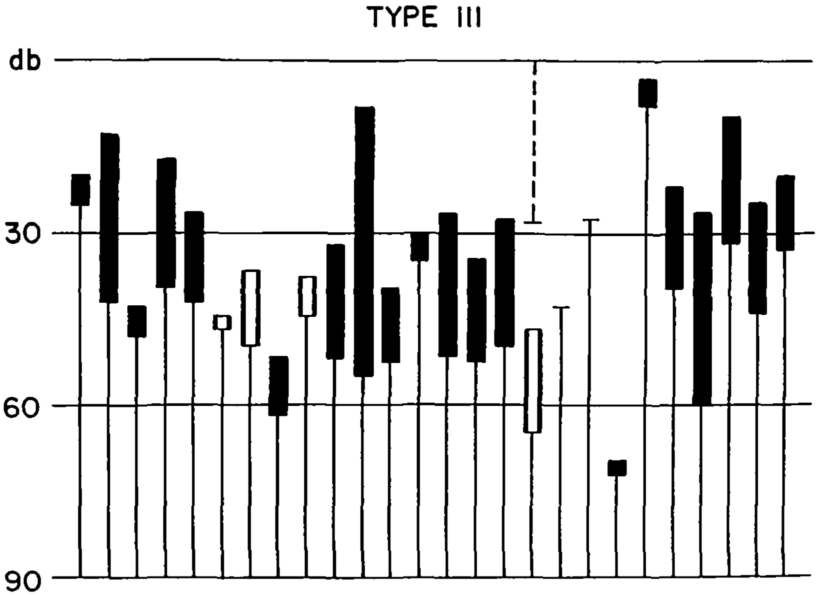

Fig 7 Tympanoplasty Type III

If the stapes footplate is mobile or can be mobilized, it is left open to the radical cavity—Type IV tympanoplasty (see Figs 8, 9) Kley[8] states that post-operative hearing with the stapes footplate alone, or with only a membranous occlusion of the fenestra ovalis is not worse than with a preserved stapes or formation of an artificial columella Seventeen cases were performed in this manner Seven reached the 30 db level of hearing, another four obtained a less satisfactory gain in hearing, one dropped below the 30 db line, and four obtained no benefit

Wulstein[4] and also Richtner[9] have reported a large number of theoretically excessively good results after Type IV tymof otology. Type I tympanoplasty has its place in closure of benign and dry perforations of the drum. Type II is not much different from the old concepts of conservative radical mastoid surgery, but with the refinements of microsurgery, combined with experience and good judgment, we can eliminate some of the failures encountered with the conservative operation. Type III is a new concept of corrective surgery with restoration of function in a large percentage of cases which previously had been subjected to radical mastoidectomy. The surgery in Type IV is a distinct and marked improvement in the treatment of advanced middle ear disease and holds much promise for the future. The old alternative was the radical mastoidectomy, and it has been demonstrated that hearing results with that procedure are markedly poor. Type V in properly selected cases, and they are infrequent, should often result in gratifying improvements due to the achievement of sound protection for the round window and the creation of a new window open to the external ear.

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1229 David Whitney Building

mastoidectomy cavities with marked hearing loss in the opposite ear The results obtained were all unsatisfactory because of one or more of the following factors Mucosal grafts were placed across the hypotympanum to the Eustachian tube and may not have been effective, excessive fibrosis was present in both windows and probably reformed in the round window, three of the grafts perforated presumably because of poor vascularity, and in two the membranous labyrinth ap-

		ABOVE 15 db	15-30 db	BELOW 30 db
TYPE II	23 cases	35 %	35 %	30 %
WULLSTEIN		30	40	30
TYPE III	26 cases	19	39	42
WULLSTEIN		15	60	25
TYPE IV	17 cases	6	36	58
WULLSTEIN		19	50	31
MODIFIED RADICAL	75 cases	37	28	35

Fig 9 Summary of results obtained in Types II III and IV tympanoplasty and comparison of results reported by Wullstein in 350 cases also results obtained in 75 modified radical mastoidectomies

peared pathological, although preoperative bone conduction tests indicated good nerve function Miodonski[9] reports three cases of Type V tympanoplasty with a markedly reduced lumen in the semicircular canal and ampulla (phthisis labyrinthi, Zange) Preoperative vestibular reactions were weak in his cases In the last case charted, one which had not been operated before, a satisfactory result was obtained

The surgery of tympanoplasty offers much to the future a surgical method for achieving this result, which they called "tympanoplasty" Since the recent publication of articles by these physicians in English and American journals, interest in tympanoplasty has been great in this country Plastic procedures on the middle ear for closure of perforations and improvement of hearing have been developed during this same period, principally by American otologists, including Juers,[5] House,[6] and Wright, Guilford and Draper[7] These techniques are most interesting, but are not within the scope of this paper

Although my experience with tympanoplasty is still limited, it was thought that some information might be gained from a brief review of my cases Between March 21, 1957, and November 1, 1957, 16 tympanoplasties were done by me at Ochsner Foundation Hospital on patients ranging in age from four to 45 years In the ensuing paragraphs selection of cases, technique, and results of tympanoplasty will be discussed in the light of this experience

SELECTION OF PATIENTS

Tympanoplasty can be performed on any patient with chronic otitis media and mastoiditis, provided cochlear function is adequate to warrant this more time-consuming and meticulous procedure I prefer myringoplasty in patients with traumatic or long healed and dry central perforations that have proved resistant to more conservative attempts at closure

Preoperative pure tone air and bone audiometry, and speech audiometry, are essential Use of the acoustic probe, as advocated by Zollner[1,2] seems unnecessary to me, because the ossicular chain and window function will be inspected at operation Its value is even questionable because of sound conduction by the diseased products present

Preoperative determination of the predominate pathogenic organism and appropriate antibiotic, followed by a period of local and systemic treatment, is desirable but not essential Disease of the paranasal sinuses and nasopharynx should be

EARLY EXPERIENCE WITH TYMPANOPLASTY (WULLSTEIN TECHNIQUE) *†

MILES L LEWIS, M D ,

New Orleans, La

Until recently it has been customary to classify chronic otitis media and mastoiditis in two general categories surgical and non-surgical The basis of this division depended upon the likelihood of extension of the pathologic process to the brain, labyrinth or facial nerve, in the opinion of the classifier, and upon the presence or absence of cholesteatoma This classification was a good, but not infallible guide, as cholesteatoma and intracranial complications can also occur in "non-surgical ears"

Numerous "modified" radical operations have been devised in an attempt to conserve or improve hearing in these patients Such procedures have often resulted in satisfactory eradication of the disease, even though some had to be converted later to radical operations, but they have been rather disappointing from the standpoint of improvement of hearing Thus the goal in the surgical treatment of chronic otitis media and mastoiditis is two-fold primarily, eradication of the disease, and second, satisfactory postoperative hearing

For many years otologists have been astounded by the occasional patient with healed chronic otitis media, or radical mastoid cavity, whose hearing was excellent On inspection of these patients it was noted that a membrane had formed, enclosing the orifice of the Eustachian tube and the round window niche, and that occasionally this membrane was adherent to the stapes Zollner[1,2] and Wullstein,[3,4] working in different universities in Germany, made these observations and began working, in the years after World War II, to devise

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*Read at the meeting of the Southern Section American Laryngological, Rhinological and Otological Society Inc Jan 25-26 1958 Memphis Tenn

†From the Department of Otorhinolaryngology Ochsner Clinic New Orleans

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Preoperative pure tone air and bone audiometry, and speech audiometry, are essential. Use of the acoustic probe, as advocated by Zollner,[12] seems unnecessary to me, because the ossicular chain and window function will be inspected at operation. Its value is even questionable because of sound conduction by the diseased products present.

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treated preoperatively Patency of the Eustachian tube must also be determined before operation

TECHNIQUE

The technique of tympanoplasty is not stereotyped, it must be adapted to the pathologic alterations present Unless intracranial extension is present or imminent, the operation is done in one stage The basic principles are simple, and have been lucidly presented by Wullstein[3,4] The principal factors in sound transmission to the inner ear are sound pressure transformation from the tympanic membrane to the labyrinth, and sound protection of the round window In Types I and II the ossicular chain is intact, and the attic is preserved, thus, both of these factors are present In Type III sound protection of the round window and partial sound pressure transformation *(through the "collumella effect" of the stapes)* are present In Types IV and V sound protection of the round window is the only factor present

If an air-containing, mucosal-lined, middle-ear space, enclosing anteriorly a patent Eustachian tube and posteriorly a freely moveable round window membrane, can be developed and maintained, useful hearing will result, provided the stapes footplate is freely moveable and cochlear function is adequate The following technique was employed in the cases in this series

A full thickness skin graft is taken, half from the posterior surface of the auricle and half from the postauricular region, as advocated by Wullstein[3,4] The margins are undermined, and the defect is closed with mattress sutures An endaural incision is made, and the posterosuperior membranous canal is removed by an incision to one millimeter lateral to the annulus The mastoid antrum is exposed by removal of bone with cutting burrs posteriorly, beginning two millimeters lateral to the notch of Rivinus A flat low bridge is formed, and all diseased mastoid cells are exenterated, care being taken to form as small a bowl as possible

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Postoperatively, all packing is removed after six days, the Gelfoam® over the graft is removed on the tenth day, and the Eustachian tube is carefully inflated on the tenth to four-

teenth day The tube is inflated at each postoperative visit thereafter, and the patient is instructed to inflate his ear carefully by the Valsalva maneuver daily

TECHNICAL PROBLEMS

In my limited experience with this procedure several minor technical problems have become evident The graft should be wide My early tendency to make the graft too narrow, and thereby produce less "pinning back" effect on the auricle, was an unwarranted fear, as in several months the auricle will assume its original position A small new middle ear is desirable, as the smaller the free portion of the graft, the less likely it is for perforation to occur A wide gap between the anterior wall of the external auditory canal and the facial ridge is desirable, the anterior edge of the graft should be bevelled, and should not extend too far laterally on the anterior wall of the external auditory canal There should be no folds or overlapping of the graft, and the stapes footplate should be left uncovered by the graft in Type IV procedures The bowl must extend to the level of the floor of the external auditory canal, and the facial ridge should be quite flat, to facilitate the placing of the graft and to permit easier postoperative care

Experience in dissection and use of the drill through the operating microscope is rapidly gained, and presents no problem Meticulous attention to detail in cleansing the stapes and round window niche is essential to a good result

It has been said "better a good Type III or IV than a poor Type I or II" The less experienced the surgeon in this work the truer is this expression The primary concern is complete removal of the disease, and plastic reconstruction of the sound-conducting apparatus will not be successful if this is not done

RESULTS

Of the 16 tympanoplasties, two were Type I, nine Type III, and five Type IV Twelve of the 16 patients have intact, inflatable middle ears Three have had perforations in the graft, one of which was closed by cauterization and patching with regain of hearing Two new middle ears have been closed by adhesions Of the two patients who had Type I procedures, one has essentially normal hearing and the other a large perforation in the graft with no gain in hearing One of the patients on whom a Type IV tympanoplasty was done is scheduled to have a fenestration operation soon The postoperative hearing status of the patients who had Types III and IV tympanoplasties is shown in Table I Labyrinthitis and other serious complications have not occurred in this series

TABLE I

Audiologic Results of Tympanoplasty Types III and IV

Type	Avg db Gain	Avg P O Air Conduction Threshold Loss in db	Max. db Gain	Best P O Hearing Level in db Loss
III	16	34	35	23
IV	14	38	32	27

CONCLUSIONS

Tympanoplasty is a tedious and time consuming, but fascinating surgical procedure The hearing gain in this series has fallen short of what is reported to be obtainable, but I have been encouraged by the early postoperative results, and believe that tympanoplasty is the treatment of choice for most patients with chronic otitis media and mastoiditis

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SOUTH CAROLINA SOCIETY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY

The next joint annual meeting of the North Carolina Eye, Ear, Nose, and Throat Society and the South Carolina Society of Ophthalmology and Otolaryngology will be held in Asheville, N C , on September 14-17, 1958, at Grove Park Inn An excellent program is in the making The following guest ophthalmologists will be present Dr James A C Wadsworth, New York, N Y , Dr Arthur Gerard DeVoe, New York, N Y , and Dr Frank B Costenbader, Washington, D C The following guest otolaryngologists will be present Dr F W Davidson, Danville, Pa , and Dr Tom Rambo, New York, N Y A third otolaryngologist will be announced in the near future A good attendance is anticipated

For further information write directly to Dr George Noel, c/o Cabarrus Bank Bldg , Kannapolis, N C , or Dr Roderick Macdonald, 330 East Main St , Rock Hill, S C

PARAORBITAL LESIONS *†

F HARBERT, M D ,

Philadelphia, Pa

This discussion will be limited to lesions which may cause signs and symptoms in the orbit and its contents, but which originate in areas adjacent to the orbit Conditions to be considered in differential diagnosis will be enumerated and illustrated by cases in my experience Anatomically, the paraorbital area consists of

1 Nose and Sinuses

2 Nasopharynx

3 Cranial cavity

4 Skin of lids and adnexa

GENERAL DISORDERS

Osteitis deformans (Paget's), osteitis fibrosa, and leontiasis ossea give characteristic X-ray findings The lipodystrophies may involve membrane bones adjacent to the orbit Diabetes insipidis and biopsy confirm the diagnosis Fibrous dysplasia, sometimes called ossifying fibroma, begins in childhood with slow progression and is often apparently quiescent in the adult It is characterized by absorption of normal bone and replacement by adult fibrous tissue in which new bone appears Histologically there is sharp demarcation between normal bone and new growth and no periosteal or other host reaction Radiographically the margins are vague

INJURIES

The tissue of the lids and bulbar conjunctiva are notoriously subject to extravasations of blood, giving the classical black

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†From the Department of Otolaryngology and Bronchoesophagology Jefferson Medical College

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eye It is interesting to note that this hemorrhage does not necessarily come from direct trauma, but is often due to diapedesis through delicate capillaries The capillaries on the lateral aspect of the bulb are most prone to this, as shown by the frequency with which extravasation occurs here as a result of excessive coughing and in rhinoplasty

Epiphora and lid edema is common as a reaction to trauma or infection of the paraorbital area Limitation of the globe and induration indicate orbital cellulitis, abscess, or cavernous sinus involvement In response to a blow, the skull and facial bones become deformed, with or without fracture This sudden deformation may cause a tear or injury to soft tissue even when fracture does not occur, as for example hematoma of the maxillary sinus associated with orbital edema

BENIGN NEOPLASMS OF NOSE, NASOPHARYNX AND SINUSES

Adenoma } usually polypoid
Angioma } usually polypoid
Chondroma
Endothelioma
Fibroma
Fibrous dyplasia (ossifying fibroma)
Hamartoma
Juvenile angiofibroma
Lipoma

Mixed tumor
Myxoma
Neurilemmoma
Neurofibroma
Odontoma
Osteoma
Papilloma (inverting)
Plasmacytoma
Teratoma

TABLE I

Blows to the zygoma often cause fractures of the orbital margin inferiorly and laterally in conjunction with fracture of the zygomatic arch In evaluating such a fracture it is imperative that alignment of the delicate plate-like floor of the orbit be determined radiographically It is well to remember that fractures here may not be demonstrable by routine films If fragments are depressed into the antrum enophthalmos results when edema subsides This used to be called fat atrophy following injury, but is due to herniation of orbital contents into the maxillary sinus by scar contraction Replacement and maintenance of these fragments by packing, inflated balloon, etc , through a Caldwell-Luc incision is usually necessary

Emphysema of the orbit may be associated with fractures involving the sinuses, particularly the ethmoid Emphysema occurring without trauma may indicate an eroding lesion, *e g* ethmoid osteoma

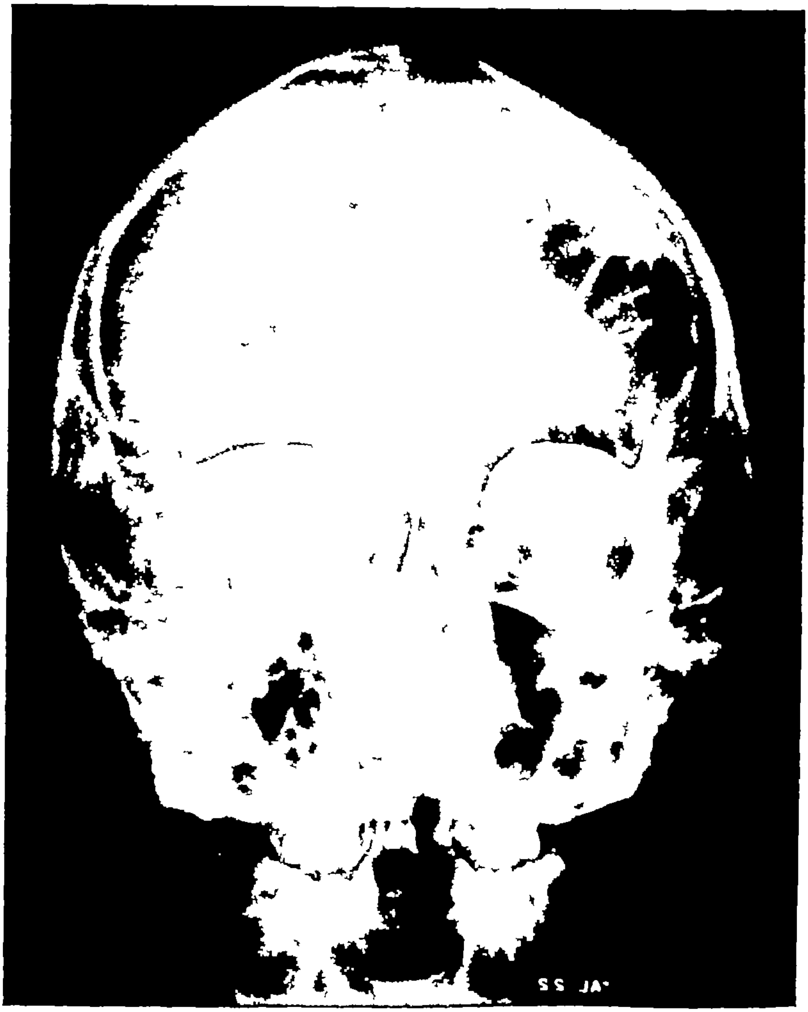
MALIGNANT NEOPLASMS OF NOSE, NASOPHARYNX, AND SINUSES

Carcinoma	Sarcoma
Adenocarcinoma	Angiosarcoma
Ameloblastoma	Chondrosarcoma
Chordoma	Fibrosarcoma
Epidermoid carcinoma	Lymphosarcoma
Neuroblastoma	Malignant schwannoma
Transitional cell carcinoma (lymphoepithelioma)	Melanoma
Undifferentiated carcinoma	Myeloma
	Osteogenic sarcoma
	Reticulum cell sarcoma (Ewings)
	Rhabdomyosarcoma

TABLE II

NOSE AND SINUSES

The relation of the nose and sinuses to the orbit is characterized by thin bony partitions with frequent dehiscences, absence of orbital lymphatics, and free anastomosis of veins We may consider that blood from the sinuses drain into the cavernous sinus via the orbit, and in sinusitis, extension to the orbit is by phlebitis The frontal sinus is insignificant below age seven, and maxillary sinusitis causes orbital complications only when there is osteomyelitis The sinuses account for 60 per cent of orbital infections Of these the frontal is most often the cause, except in younger children where ethmoid disease is more important[1] Granuloma may be specific, *e g*



Chondrosarcoma of the nose causing unilateral proptosis and bilateral visual impairment

Fig 1 Indeterminate findings by usual views

scleroma, yaws, syphilis, etc, or non specific The midline (lethal) granuloma remains an enigma Cysts such as dermoid and dentigerous may extend into the orbit

SINUSITIS

Acute fulminating frontal sinusitis may occur in younger individuals with normal sinuses, often after swimming Acute

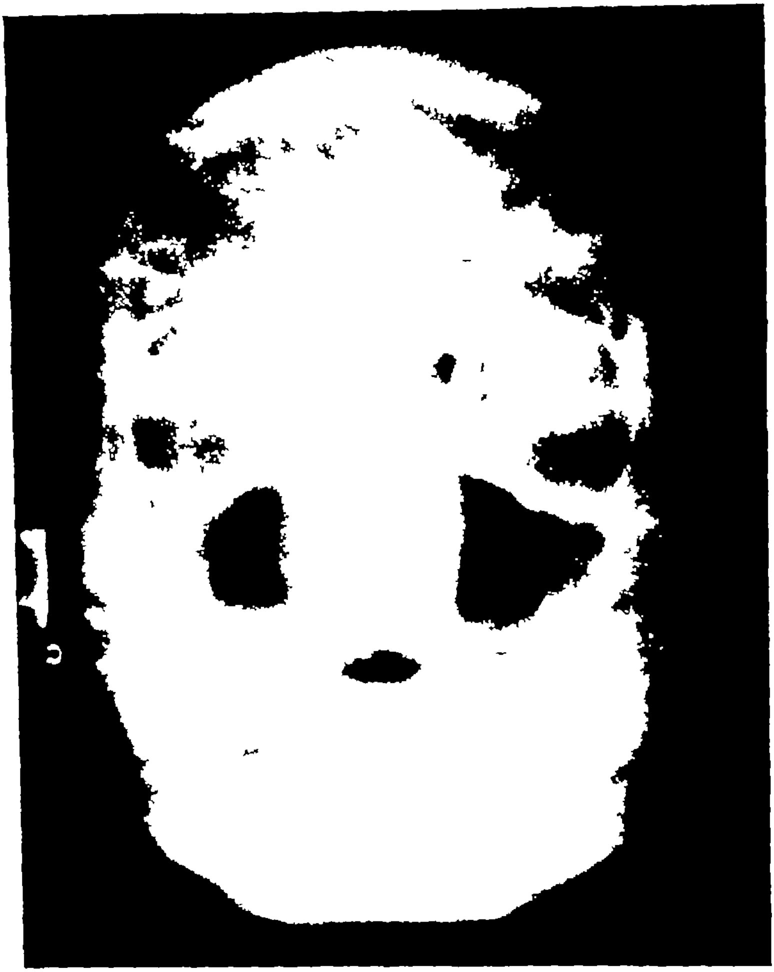


Fig 2 Planigraphic demonstration of tumor

Exacerbations of chronic disease, or recurring acute attacks indicate underlying pathology such as inadequate aeration Obstruction is in the nasofrontal connection, and not in the nose Such procedures as removal of nasal polyps, infraction or amputation of the middle turbinate, and submucous resection may be indicated, but rarely relieve the basic obstruction

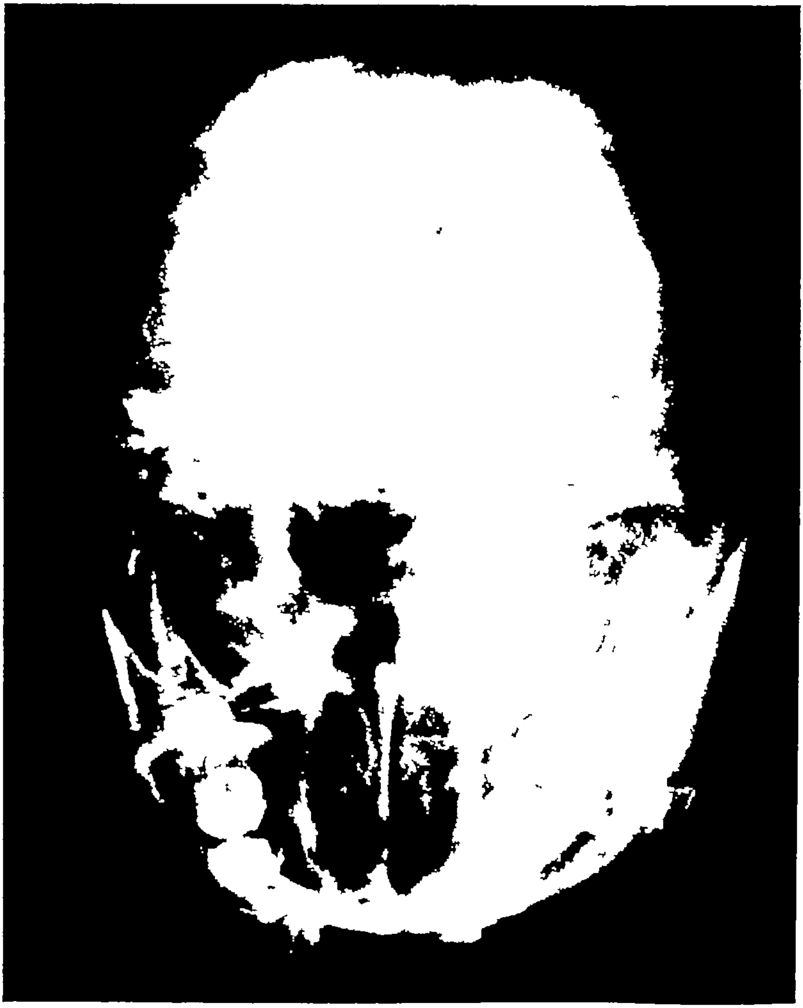


Fig 2a. Basal view of skull showing encroachment on nasopharyngeal airway and obliteration of foramana and Eustachian tube

Nasopharyngeal lymphosarcoma causing proptosis paralysis of the VIth nerve and extension to middle and external ears on admission Complete regression under X-ray therapy with subsequent metastasis to lungs

Bone reacts to infection by either proliferative or destructive changes The former is commonly seen as a condensing osteitis of the sinus wall, and usually indicates a chronic and milder process than demineralization Sinus tracts may extend to the lids or orbit Local destruction of marrow (osteomyelitis) indicates a more acute process Because of intimate venous connection between marrow spaces, dura, and periorbita, both intra cranial and orbital complications may occur in the osteolytic type Reactive orbital edema is common with acute sinusitis

Mucocele Mucocele causes erosion and absorption of adjacent bone with encroachment on the nose, orbit, and dura The frontal sinus is most commonly involved in adults, and the ethmoid in the young The maxillary and sphenoid sinuses are rarely affected The symptom calling for medical attention is usually painless deformity—in the case of the orbit proptosis Diagnosis is usually made by X-ray, which shows thinning of walls and obliteration of normal scalloping of the frontal sinus or coalescence of ethmoid cells Periodic ophthalmoplegic migraine and proptosis may indicate sphenoid mucocele If a mucocele exposes both the periorbita and the dura there may be a pulsating exophthalmos

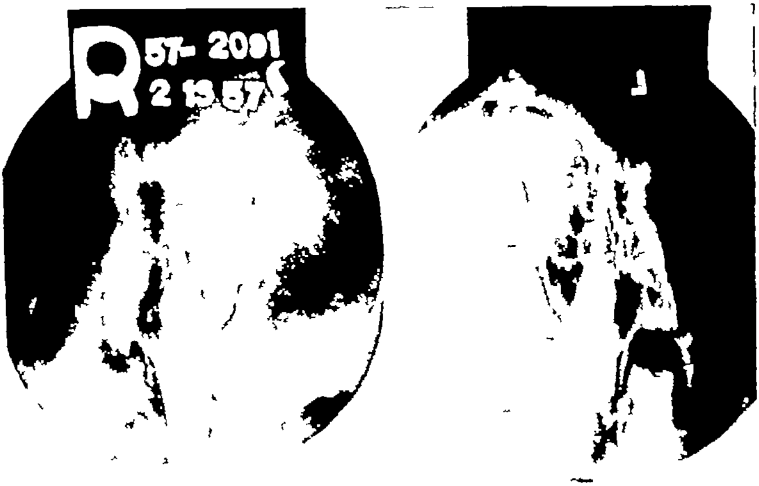


Fig 2b Mayers views showing coalescence of external coral antrum and adjacent cells

Neoplasms Tumors involving the orbit occur approximately as follows [6] primary 60 per cent, paraorbital 30 per cent, metastatic 10 per cent

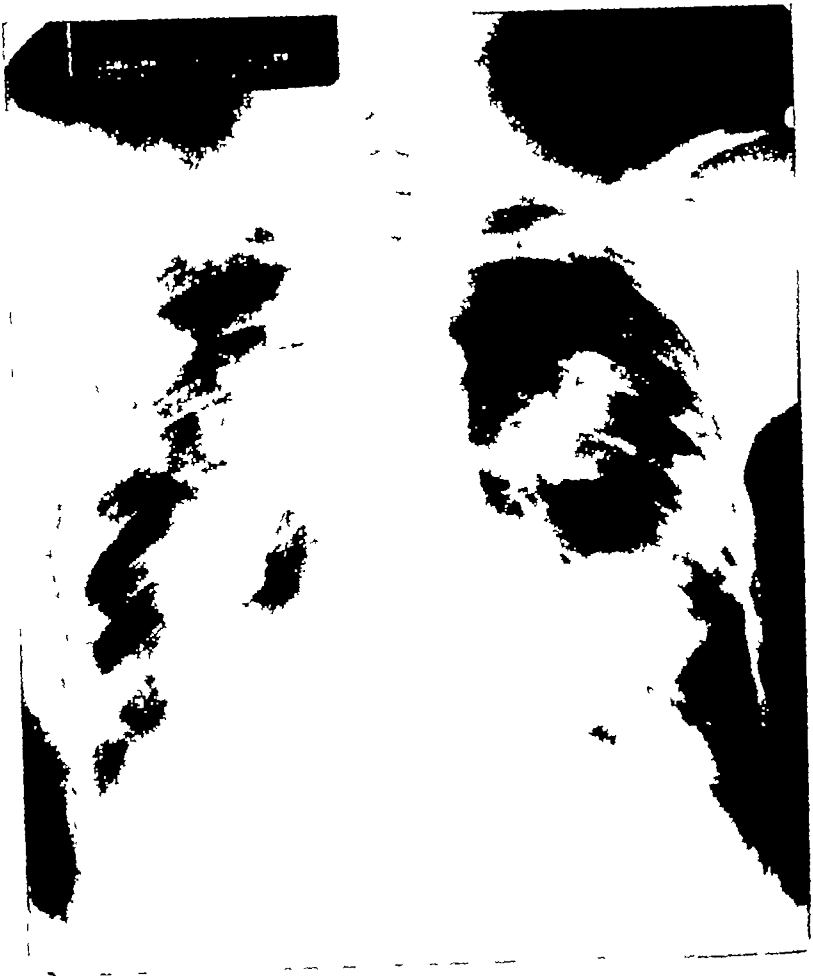


Fig 2c Pulmonary metastasis

The eye is able to adapt to slow invasion of the orbit, as by a benign tumor without the development of diplopia, or limitation of excursions even when proptosis is marked The development of diplopia and reduced mobility with little proptosis is, therefore, an indication of a rapid orbital invasion, and is more characteristic of a malignant tumor [1]

Nasal polyps of the mucoid type practically never encroach on the orbit, but the presence of nasal polyps may mask more deep seated disease Repeated biopsies, sometimes through external incisions, may be necessary to establish the presence of a neoplasm The use of iodized oil, Papanicolaou smears, and aspiration biopsy have questionable value, in that a positive finding must be confirmed by open biopsy, and a negative finding is valueless[3] The presence of unilateral polyps and discharge, or epistaxis, particularly warrants thorough study[3]

Osteoma is an encapsulated bony tumor originating from disturbed or displaced cartilage Cortical, cancellous, and mixed varieties are recognized They are slow growing and produce symptoms by obstructing passages causing mucocele or secondary infection, sinus tract formation, or encroaching on adjacent orbital or cranial areas The frontal sinus is involved in one-half of the cases, the maxillary in 10 per cent, and the ethmoid in the rest[14] Sphenoid involvement is very rare

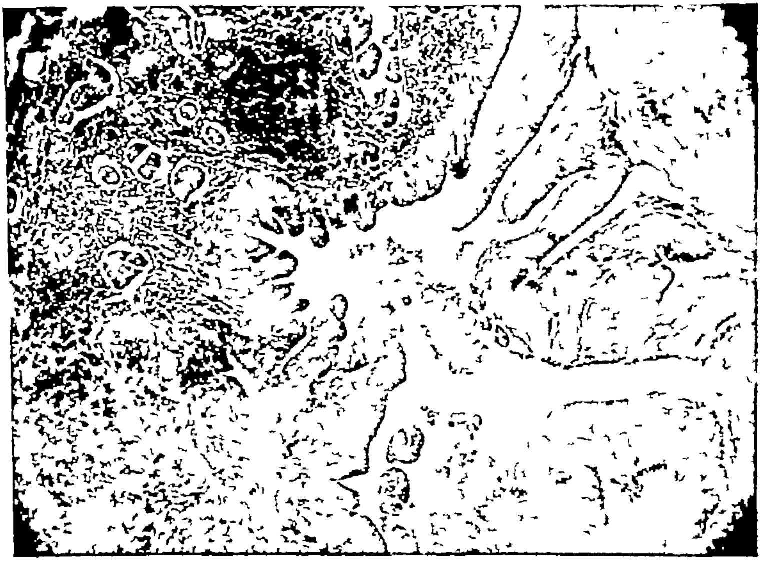


Fig 3 Basal and squamous carcinoma of lids with extension into orbit requiring exenteration and metastasis to cervical lymph nodes

Carcinoma of the paranasal sinuses constitute only 0 2 per cent of all carcinoma[3] Of these by far the greatest number originate in the antrum, and the balance in the ethmoid The frontal and sphenoid are usually secondarily involved[1] Males are affected twice as often as females for both osteoma and carcinoma Unless the tumor originates superficially and causes early obstruction or bleeding, the diagnosis is usually made late X-rays usually fail to reveal the full extent of the lesion

NASOPHARYNX

Malignant tumors of the nasopharynx constitute about 3 per cent of all malignancies, and are most often epidermoid in the adult and sarcomatous in the young They may spread to the orbit, intracranially, or along the Eustachian tube The peritubal syndrome (triad of Trotter) consists of deafness due to serous otitis media, neuralgia due to involvement of the mandibular division of the Vth nerve and palate palsy The syndrome of the orbital apex (petrosphenoid syndrome) consists of palsy of one or more nerves II, III, IV, V, VI, and the sympathetic (Horner's syndrome) The orbit becomes involved by extension in the foramen lacerum along the carotid artery to the superior orbital fissure, or by extension from the pterygoid space to the inferior orbital fissure Deep seated parotid tumors may affect the orbit by the latter route Some primary malignant lesions may not be recognized, even in the presence of cervical metastasis, which occurs in 75 per cent of cases In 50 per cent, the first symptom is ocular, *viz* diplopia, pain, or reduced vision Fifteen per cent have symptoms referrable to the ear—pain, fullness, deafness, as the initial complaint[1] Any case of otherwise unexplained cervical adenopathy, otalgia or deafness, facial pain or anesthesia, or diplopia, should have a thorough examination of the nasopharynx and biopsy of any suspicious lesions

Juvenile angiofibroma occurs usually in male adolescents, grows to about age 25 and then recedes It may originate from any part of the base of the skull, often with multiple attachments It absorbs adjacent bone by slow growth, and may extend intracranially into the orbit, nose, sinuses, and sphenopalatine fossa Recurrent severe epistaxis, nasal obstruction, or secondary sinusitis is common Biopsy of such a tumor had best be done in the operating room

Chordoma is a tumor originating from the cranial end of the notochord It may occur in the nasopharynx, sphenoid or intracranially X-ray may show a bony defect at the site of the tumor A partial list of other tumors to be considered is shown in Tables I and II

SKIN AND ADNEXA

Malignant tumors of the skin may extend into the orbit Lid tumors are frequently baso-squamous It is well to remember that while basal cell tumors practically never metastasize, the baso-squamous type do When an epidermoid lesion involves only soft tissues, treatment by either radiation or surgery may be considered When bone is involved the prognosis is grave, and treatment by any method is difficult, but surgery provides a better prognosis than radiation Acute inflammatory processes of the skin or lachrymal sac may cause orbital cellulitis or abscess, while chronic lachrymal sac infections may produce sinus tracts

CENTRAL NERVOUS SYSTEM LESIONS

Central nervous system lesions, causing orbital symptoms may be considered under the heading of tumors, cavernous sinus thrombosis and A V aneurysm

Probably the most common intracranial tumor associated with the orbit is meningioma arising in the vicinity of the sella or sphenoidal ridge The latter may extend into the orbit as well as intracranially Marrow bone adjacent to such a tumor often reacts by causing hyperostosis while cortical bone is absorbed Characteristic X-ray findings and the syndrome of the orbital apex are diagnostic Proptosis and optic atrophy usually precede neurological findings and pituitary dysfunction Pituitary tumors extending into the sphenoid may be best treated by the otolaryngologist

Cavernous sinus phlebitis is usually due to toxic swelling of the endothelium and thrombosis to stasis The original source of infection may be as follows

1 Skin of the face (especially the lids, lip, and scalp, via angular and superior ophthalmic veins)

2 Nose· (via ethmoid and ophthalmic veins)

3 Teeth (via pterygoid plexus and inferior ophthalmic vein)

4 Ear and Mastoid (from lateral sinus or via petrotympanic fissure to pterygoid plexus and inferior orbital vein)

5 Throat (via pterygoid plexus and inferior ophthalmic vein)

Cavernous sinus thrombosis may also occur in blood dyscrasias and septicemia

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THE WONDER DRUGS—A PSYCHOSOCIAL PHENOMENON*

LESTER L COLEMAN, M D,
New York, N Y

It is said that the history of civilization has as its mirror the history of medicine The art and practice of medicine has been intimately interwoven into every phase of man's accomplishments, for always the history of a nation's economy, growth, intellectual and artistic attainments have been dependent upon the health of its people

Revolutionary concepts in science and medicine have through the ages opened new horizons and new vistas for the study of man Every generation seems to have brought with it newer accomplishments, newer therapeutic techniques, newer diagnostic facilities, all bringing with them a growing feeling of encouragement and hope

All therapies from time immemorial have had as a valuable ally an aura of magic and sorcery Even today disease is still enshrouded by a veil of mystery Invisible pressures, apparently beyond the control of the individual, seem to exert forces that convert health to illness Disease seems to be endowed with special malice governed by an invisible mystic force Fevers, chills and anxieties uncontrollable and unyielding have been recorded as having these mysterious overlays Disease is considered capricious and punitive, especially by those plagued with guilt for real or fancied sins

Mores are different in all civilized and primitive societies The character of the taboos may vary with special enlightenment, but the violated taboo always suggests that disease is punishment for sin and guilt The invisible devil exerting his malicious charms is given special credit for the causes of disease Civilized societies impose similar supernatural quali-

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ties to the mysteries of modern-day illness We, too, seek the cause of disease in quasi truths and fiction, departing slightly from the primitives who seek theirs with magico-religious incantations Magic, the unexplained, is as vital an element in the healing as in the cause of disease

The potency of the sorcerer and the efficiency of his art, regardless of the nature and cause of sickness, lies in the magical healing qualities of his prescription The greater the rarity, the greater the difficulty in obtaining it, the greater the expense, the greater is the potential curative power of that drug Rarity is the exploitable element in the sorcerer's armamentarium of magic Exorcism, one of the precursors of the psychosomatic concept, was a potent technique against any spiritual intrusion The magico-religious implications of the etiology and cure of diseases has its specific roots in the social and economic structure of any particular society Therapy in primitive society is rational in terms of its particular world of magic and the supernatural For these primitives it is logical and predicated on the faith in the tribal healer The rapport between the savage and the sorcerer, his medical consultant, is solidified by exquisite faith based on past accomplishments Witchcraft and black magic, born of scientific limitations in primitive society, has its exact counterpart in the medical practices of today's society

All therapy has evolved through distinct periods of ignorance and truth The parallel relationship between disease and therapy can be used for study of one or both At first all therapy was magical, mystical and religious, and had no basis in fact Therapy was then nonempirical and based on illogical postulates The next phase of enlighenment was the pre-scientific era when therapeutic procedures were based on abstract or metaphysical ideas, combined with the beginning of the empirical approach Later came the positivistic or early scientific attitudes toward therapy based on the study and observation of natural phenomenas Unfortunately, during this period there was as yet not enough interdisciplinary knowledge for the adequate explanation of these anatomical and physiological phenomena

The era into which we have grown with scientific maturity is one whose accomplishments are based on scientific postulates, scientific observations and thorough analysis Therapy attained its full maturity with the realization that no science can be isolated or insulated from all other biological, philosophical or social disciplines The therapeutic ultimum could only be attained by extensive interdisciplinary exchanges of all allied information

The advances and correlation of this interdisciplinary knowledge is rapidly bringing us to a peak of scientific accomplishment Physical, chemical, biological and social studies, combined with psychoanalytical disciplines, are all represented in this mature humanistic era of medicine Medicine incorporates these scientific studies, piloted by the physician who applies them for clinical therapy The horizons have thus been expanded for today's doctors They must not be burdened or limited by any sociological pressures and revert to ancient concept of therapy

Language is the basic means of communication between the doctor and the patient, yet each speaks a different language, one that needs amplification and explanation The confusion of this language barrier is elaborated because the patient seems to "hear with an accent" The patient listens but hears with a distortion born of the tensions and anxieties of illness Illness destroys the emotional stability of many patients, or at least alters it It is in this off-balance position that they first make contact with their doctors Long after the disease and its devitalization has passed, the doctor continues to be identified with painful symptoms, complaints, alteration of productivity and financial burdens Thus the physician evolves as a predatory subversive who parasitically thrives on the patient's misfortune

The doctor is considered by the patient as the possessor of infinite wisdom, and is invested with the cloak of symbolic reverence and adulation Subtle pressures are imposed upon him to maintain this precarious position of limitless knowledge Rarely is he permitted the luxury of saying "I don't know" or "I will find out" Answers are a must, even if fiction is substituted for fact Fiction thus created must later be denied or confirmed with additional fiction. Errors thus become fixed in the mind of the patient who is convinced of the omniscience of his doctor. For, a simple thought, cloaked in a polysyllabic phrase, can become a confusing enigma reaching culmination in wonderment and awe by the patient.

There are many such paradoxes in the doctor-patient relationship that must be reconciled before complete solidification of this important unity is to be achieved. Patients resent being emotionally and physically undressed and exposed to the intricate and labyrinthine investigations that seem to be aimed at the annihilation of their personal ego. The doctor sometimes sadistically enjoys the authoritarian position that allows him to intrude into every crevice of the patient's life. Doctors have been enveloped with a halo of godliness for so long that they have grown to enjoy its magical potency.

Many doctors are offended when their right to their godlike pinnacle of prominence is questioned. They wear their protective cloak of godliness, fearing only that if defrocked they will reveal their human frailties and expose their medical inadequacies.

The desperate need and impulse to "do something" is the doctor's response to anxiety superimposed on him by the patient. The stress of fear and anxiety that invariably accompanies all disease makes urgent therapeutic action a necessity. This stress is a profound pressure on the relationship between the patient and the doctor. It is the same pressure of anxiety which expressed itself in sacrifices at the altar or in visits to the shrine of an oracle. It is the same impulse that led primitives to search out the strange herb for concoctions for the sick. Ignorance of the potential or the ingredient of the herb played no part in the motivations to give it. Out of this sociological pressure has grown the philosophy of the placebo. Medicine has never been divorced from this concept. Implicit in the function of all drugs, with or without a specific pharmacological action, is the important emotional value of the placebo. Even the antibiotics, used judiciously to destroy a specific organism have the distinct emotional overtones of the placebo.

It is not my purpose to become too involved in general semantics or in psychoanalytical interpretations May I be forgiven if I recall that a fundamental to the relationship between the doctor and the patient is the need for dependence and perhaps a regressive infantile need for punishment The authoritarian personality, the protector, the physician becomes the embodiment of support and security of the parent Patients classified as placebo reactors with a distinct evidence of suggestibility are the passive dependent types who rely on the authority of the doctor

Any medication prescribed by the physician carries with it the hope of fulfillment and protection The medication takes on an emphatic projection of the doctor's personality and becomes in essence a symbol of support, of faith and even of spiritual wisdom The actual chemical ingredient has as a hallmark of authenticity the faith in the doctor's judgment There is then a skillful art in the balanced use of the placebo It is not a means of deception, of fraud or misrepresentation, yet there can be but a delicate semantic nuance between its honest and dishonest use When the placebo is used as a technique to disguise our scientific inadequacy, it is inexcusable When drugs with a placebo effect are endowed with supernatural powers to compensate for our limitations their use is also inexcusable The placebo can never be used to absolve the physician from the obligation to differentiate critically between the physical and emotional needs of the patient

Moral values and their interpretation have insinuated themselves into the controversy for and against the use of the placebo Lost in this controversy of morality were the specific needs and emotional equipment of the patient that dictated their use

Illness is a threat to the integrity of the patient The placebo as a specific form of therapy can serve as an additional tie between the doctor and the patient The need for all therapy diminishes in direct proportion to the growing strength of that binding tie Their strengthened relationship strips all therapy of affectations, pragmatic lies and purposeless distortions

The art of therapy is a discriminating art. Factors apparently far removed from the etiology and diagnosis of disease determines therapeutic decisions. The art of treatment is intimately a part of the intricacies of the doctor-patient relationship. Drugs, especially the newer antibiotics, have become the property of both the doctor and the patient. When the sulfonamides and later the antibiotics were introduced, the press rapturously exalted their supernatural powers. These drugs were immediately considered as mystical throwbacks, first because their life-saving action was so poorly understood, and second because of their comparative rarity. Rarity again became an element exploited by those who ascribed to these drugs the title of "wonder." Their physiological action and specific characteristics to defend the body against the invasion of attacking organisms were lost in the excitement of the newness. Rather were the wonder-drugs considered as some magical derivative that had the specific power to exorcize all disease. Modern medicine temporarily reverted to the magical, mystic phase of pre-scientific medicine.

The sulfonamides and the antibiotics, by their very title of "wonder drugs" were given an extra mundane aura of magic. They gracefully took their place among the many drugs about which there still persists an inherited feeling of mysticism. Because the announcement of the discovery of the wonder drugs came to the laity at the same time that it came to the doctors, via press, radio and television, patients seemed to feel that they, too, had as great a proprietary right of possession of the drugs as did their contemporaries, the doctor, patients felt that unless the doctor actually discovered penicillin himself, he could not rightfully consider himself any greater expert in its administration than the patient himself. From then on, so-called qualified experts sprang up everywhere. Recovery from any illness and the correct pronunciation of the responsible drug fulfilled the basic requirements for admission to the lay society of therapists. For a long time after Fleming discovered penicillin the importance of its contribution was overshadowed by endless discussions as to whether it was to be called peńicillin or penicillin. If I recall correctly, a publication was released by a Committee of Eight which finally gave the news to the world, not of the great action of the drug, but of its correct and properly authorized pronunciation, penicillin

Gleefully and rightfully the patient rubbed his hands in delight at the possibility that the physician would slowly become extinct Dinner parties could always be rescued from boredom by a commiserating discussion of the dwindling need for doctors in the community Here for the first time was an opportunity to volatilize their stored inner rages against the doctor, the golem of all illness The immediate disappearance of all acute mastoid surgery was considered a kindness to mankind, but more important the first step in the total eradication of that parasitic vulture, the tonsil-snatching, septum-slicing butcher of butchers, the otolaryngologist

Specialists in all other fields were being slowly eliminated, too, as the antibiotics were finding wider and wider use, in fact, the only field that seemed safe from the onslaught of the antibiotics was psychoanalysis, and it is now facetiously rumored that a potent antibiotic is in the making for covert homosexuality

Chemotherapy and the antibiotics have taken a unique position in the important sociological relationship between the doctor and the patient This position has as great a potential for good as it has for harm The patient now demands and supports his demands for a specific drug, at a specific time, with a subtle threat The special weapon, the ace in the hole to support his insistence is the "give or else law of no return" Either the doctor gives the antibiotic or the patient threatens to go somewhere else Many patients have thus revolted from their previous position of subservience to enjoy new found control over the authority of the doctor There was now a restoration of the balance of power which they had so reluctantly yielded to their physician If I may be permitted the luxury of a pun, there is now an "intermycin intrigue" for the retention of the weapon of dominance

Though this pressure may not always alter the integrity or the therapeutic motivations of the doctor, it may alter his approach to the treatment of that particular patient He recognizes that the patient will ultimately obtain the shot of wonder drug somewhere, and thus succumbs to the pressure of the patient's demands Loss of therapeutic integrity is coincidental with the position he forfeits when he becomes a tool buffeted by the whim and fancy of medical ignorance Having fallen into the pressure trap of the social use of the wonder drugs, he finds it difficult to extricate himself and is forced to perpetuate that initial error This is the penalty for giving too great importance to these drugs and indoctrinating the patients in their miraculous misconceptions

The demands for a rapid cure has forced the doctors into competition with each other and with themselves Speed of cure has become the critical value in the expansive pride of possession of the patient for "their" pediatrician, "their" obstetrician, "their" nose and throat doctor Speed of recovery always substantiates the magnified enthusiasm that makes their doctor "the chief of the department" or "the head of the hospital" To have less than "the chief" is a social disadvantage An unimportant doctor and an unimportant disease can be a social handicap in the caste-like system of "illnesses" New therapy, even when scientifically unconfirmed, adds special distinction Patients sometimes vie with each other for the special privilege of being an experimental "guinea pig" for a new antibiotic There is nothing more destructive to the vanity of the patient than the doctor's casual statement that "the disease was relatively unimportant and would have gone away by itself" Recently it became a sign of social distinction to have had the first case of imported Asian flu in the community

Antibiotics do not live by "molds" alone The virus is a sly little fellow that has slowly insinuated himself into the practice of medicine as a subversive character His position is made secure by those of us who exploit him to preserve the sanctity of our trade unionism The virus is dead, long live the virus Without him our inadequacies might be showing The virus flourishes luxuriantly on the nutrient medium of ignorance It can always be depended on to extricate us from any untenable medical position The virus is a comfortable refuge to explain the unexplainable It seems hardly fair to use the antibiotics so injudiciously and promiscuously to destroy such a valuable ally These two sociological elements, the virus and the antibiotics have joined forces and become a potent factor in our choice of therapy Many years ago the magical power of the sulfonamides was said to cure the first virus I ever encountered This was a six-day virus, a slow moving, unimpressive, undistinguished virus Next came the forty-eight hour virus, cured dramatically with penicillin The cure was fast, the drug was greater, the doctor was the greatest We are now in the jet propelled two-hour virus phase, cured by "my doctor" with the triple acting wonder drug that contains "god all" Time records for cure have been broken with regularity The cure now is so rapid that the patient barely has time to complain

Many truths are interwoven in this apparent facetiousness

Physicians and patients have been equally responsible for distorting the delicate balance of their vital relationship Patients had been given remarkably little credit for their capacity to understand the complexities of their medical problems, but almost invariably this apparent lack of understanding was based on our inability to explain, rather than on their inability to comprehend The laity is receptive to unconfused and undistorted medical information They welcome precise explanations of our discriminating decisions for or against specific use of the sulfonamides and antibiotics They now appreciate the disadvantages of the unbridled use of any drug, for they have learned, usually by sad experience, about the side effects and toxic reactions of these drugs They have a new and profound respect for the danger in the promiscuous use of any drug They have come to realize their inadequacy in guiding their own course of therapy

Physicians everywhere are relinquishing their position as a drug giving cult They are revolting against the social pressures of the patients who dictate their own antibiotic therapies, but with this revolt comes newer enlightenment and recognition that the emotional needs of patients cannot be supported by the promiscuous use or abuse of antibiotic therapy

Fear and anxiety is a constant in the equation of health and illness, the evaluation, therapy, and prognosis of all disease must always include its recognition For there is but one yardstick and one criterion by which we can actually measure the intensity, the severity and duration of an illness The touchstone that guides us is only the return of the individual to complete serviceability and productivity Not until the individual is totally rehabilitated and returns to serve as a functioning part of his home, job and community can that individual be considered free of his disease The cessation of a cough, the return of fever to normal, the normal sedimentation rate or electrocardiographic findings are never the critical criterion of the return to health For many patients who are ostensibly cured fail to take their place in society because of the devastating fear that the illness may soon return It matters little whether the individual is not serviceable because he has had a heart attack or is afraid that he will have one It matters little if a man cannot function because he has a carcinoma of the larynx or lives in constant fear that he will have one The devitalization by fear of impending disease can be infinitely greater than the disease itself Rehabilitation, reestablishment of normal patterns of living are the *only*—*yes*, the *only*—way that we can determine the efficacy of our therapeutic approach It becomes evident, therefore, that no diagnostic or therapeutic concept of medicine can be divorced from an understanding of the psychological overtones that invariably accompany every disease to which the body is heir

This harrassed world carries with it newly conceived fears that destroy our complacency The practice of medicine notes with growing concern the increase in the number of patients who are overwhelmed with fear and anxiety, often completely out of proportion to the severity of their illnesses Minor, relatively insignificant disease seems to catapult patients into an emotional tailspin by the propulsive force of their unreasoning fears

For many, this fear is far more destructive than disease itself Anxiety seems to dominate their behavior during and sometimes long after their illnesses This anxiety is not characteristic of any one sex, age, occupation, social and intellectual level, or ethnic, religious and geographic group The timid, the stoic, the shy and the stalwart seem to be equally affected by an overlay of fear about the illnesses they have, or more often think they have There may be variations of the intensity of the anxiety and the ease with which it can be alleviated, but no one appears to be completely free of it Patients, children, adolescents and adults are afraid, just afraid! Their fears as well as their illnesses determine how quickly and how well they will be reestablished in their schools, jobs or homes

Fear in itself is an illness The fear that we physicians observe in our offices is actually a communicable disease It is not transmitted by germs or by virus It is transmitted by humans to humans, sometimes unwittingly, sometimes in error, and sometimes purposefully For "Fear" is big business, and is often exploited by propaganda agencies under the guise of public medical education Fear of all disease, fear of heart disease, fear of cancer, fear of tuberculosis, fear of arthritis, fear of cataclysmic destruction by atom bombs, fear of economic upheaval, and now fear of the consequences of smoking, all become a never-ending bombardment against our inner security We have but to note the penalty paid by the public during their "education" about tobacco, Salk vaccine and Asian flu

Fear is everywhere, it is all-pervasive, slowly, deliberately it seeps into our physical, emotional and spiritual fibers To paraphrase Emerson, fear is a circle whose circumference is everywhere, and whose center is nowhere

Fear is a force, fear is an illness, it can alter the destiny of those who, by concession to this fear, distort their behavior in response to it It can play havoc with careers, social attainments, the relationship between husband and wife, and the relationship between parent and child

Fear does not "stand up to be counted," its greatest potency lies in being hidden Because it cannot be counted, it is not adequately charted in the statistics of the diseases of man, even though it ranks as one of the greatest threats to emotional and physical health

Fear, the product of this harried, frenetic Twentieth Century is a sociological phenomenon It activates many in their demand for miraculous therapy Uncontrolled it destroys the rational relationship between doctors and their patients Fear, as a disease and as an element in all disease, is readily communicated Fear flourishes in epidemic form and slowly insinuates itself into every facet of our civilization, but like all other diseases, fear is vulnerable and yields to its own miracle drugs—hope and courage, psychologic education and freedom from ignorance and superstition These, too, are wonder agents that are swinging the pendulum back to therapeutic sanity The wide spectrum of the use of wonder drugs must include judicious understanding and critical therapeutic evaluation Social pressures and prejudices must not dictate medical indications or specific choice of the "wonder drugs" if they are to survive in their rightful position as one of the greatest scientific contributions to mankind

162 East Eightieth Street

IN MEMORIEM

Gabriel Tucker, M D

1881-1958

Dr Gabriel Tucker, a native of Fairmont, W Va , died at his home in Rosemont, Pa , April 18, 1958

The degree of Doctor of Medicine was granted to Dr Tucker by Jefferson Medical College in 1905, and he practiced in Pittsburgh and its environs until joining the Army Medical Corps in World War I, in which he served abroad at Base Hospital 126

Widely known for his use of the bronchoscope and for his skill in the removal of lung cancers, he became Professor Emeritus of broncho-esophagology at the University of Pennsylvania Graduate School of Medicine and worked in the field as an associate of Dr Chevalier Jackson in the first bronchoscopic clinic at Jefferson Medical College Two years later he was named a charter member of the broncho-esophageal department upon the establishment of this clinic of the Pennsylvania Graduate School of Medicine

The Gabriel Tucker Fund for the department of broncho-esophagology was established in 1949 at the Graduate School by an anonymous gift of $200,000

Together with Dr Chevalier Jackson he conducted the first course in laryngeal surgery in the European medical schools

Dr Tucker was a member of the American Academy of Ophthalmology and Otolaryngology, from which he received the Honor Award in 1955, he was a past president of the American Laryngological Association and past secretary and chairman of the Section on Laryngology, Rhinology and Otology, of the American Medical Association, and was a Fellow of the American College of Surgeons

Surviving are his widow, three sons and four grand children

SUBCOMMITTEE ON HEARING IN CHILDREN

The American Academy of Ophthalmology and Otolaryngology, through its Subcommittee on Hearing in Children of the Committee on Conservation of Hearing, has been conducting a long-term nationwide study of problems relating to the conservation of hearing in children The specific aims are to develop the most efficient case-finding methods and to use these methods in estimating the magnitude of the problem in the country, to study state laws and review current practices and facilities for rehabilitation of hearing impaired children, to help develop methods for medical and surgical rehabilitation standards, and ultimately to use the Subcommittee findings in assisting professional workers to improve and enhance programs in hearing loss

In the second year of operations, a full-time Executive Director has been engaged, and offices established at the Graduate School of Public Health, University of Pittsburgh An initial study is being conducted in Pittsburgh to identify early medical signs and symptoms which may indicate danger of hearing impairment, to measure the psychological, social and other effects of such impairment and to develop efficient and economical methods for the testing of hearing in children The Pittsburgh study is a cooperative effort among the following The Subcommittee on Hearing in Children, the Graduate School of Public Health and the School of Medicine of the University of Pittsburgh, the Pittsburgh Board of Public Education, and the Allegheny County Department of Health

The members of the Subcommittee on Hearing in Children are Dr John E Bordley, Baltimore, Dr Victor Goodhill, Los Angeles, Dr Hollie E McHugh, Montreal, Dr S Richard Silverman, St Louis, and Dr Raymond E Jordan, (Chairman) Pittsburgh An advisory committee of consultants from the University of Pittsburgh includes Dr Samuel M Wishik, Dr Leo G Doerfler, and Dr Isidore Altman Grants from the United States Children's Bureau through the Pennsylvania Department of Health and from the National Institutes of Health are providing financial support

REINE HUMBIRD MYERS FELLOWSHIPS IN AUDIOLOGY AND HEARING SOCIETY ADMINISTRATION

The American Hearing Society and its member agency, the St Paul Hearing Society, announce two Reine Humbird Myers Fellowships for a two-year program of graduate study at Northwestern University, annual stipend $3,000, for students interested in a career combining the professional and executive responsibilities of Hearing Society work

Fellowships are open only to students who are acceptable to the Graduate School of Northwestern University, and who intend to take key positions in local Hearing Societies upon completion of the Fellowship training in Administrative Practices, Agency Procedures, Clinical Audiology and Speech Pathology

The program covers two calendar years The sequence of study will ordinarily lead to the Master of Arts degree Studies include courses in phonetics, basic audiometric techniques, speechreading, auditory training, and speech development, psychology of deafness, community programs in audiology, hearing aids and their selection, advanced audiometry, anatomy of the hearing and speech mechanisms, principles of speech correction, and elective areas The program also includes courses in social work, plus clinical experience and field activities

The resources of the Graduate School of Northwestern University are combined with the educational facilities in social work found in the Chicago area Special opportunities for practical experience are available at the Chicago Hearing Society and in clinics maintained by Northwestern University

Each candidate must submit to the American Hearing Society (a) transcripts of his academic record, (b) a personal statement describing his background and expressing his professional aims and goals, and (c) names of five references, including at least one college instructor and one employer or work supervisor The candidate must also apply for admission to the Graduate School of Northwestern University, and must notify the School of Speech at the University that he is seeking a Reine Humbird Myers Fellowship

INSTITUTE ON INDUSTRIAL DEAFNESS

Colby College, Waterville, Maine, presents the Sixth Annual Institute on Industrial Deafness, August 11-20 inclusive Please note that the course has been extended for three days in order to include engineering for noise control Its objective will be to train physicians interested in the problem, nurses, plant engineers and others in initiating and conducting hearing conservation programs in noisy industries The course includes basic otology, audiometry, noise measurement, ear protection and methods of noise control Class is limited to approximately twenty participants

The fee for the course is $250 and includes tuition, room and board The first week will constitute a complete course for doctors and nurses, and the reduced fee for this will be $200 Application should be made to Mr William A Macomber, Colby College, Waterville, Maine

DIRECTORY OF OTOLARYNGOLOGIC SOCIETIES

(Secretaries of the various societies are requested to keep this information up to date)

AMERICAN ACADEMY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY

President Dr Erling W Hansen 90 So Ninth St., Minneapolis, Minn.
Executive Secretary Dr William L Benedict, Mayo Clinic Rochester, Minn
Meeting Palmer House Chicago, Ill

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Meeting Palmer House, Chicago, Ill

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AMERICAN LARYNGOLOGICAL ASSOCIATION

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AMERICAN LARYNGOLOGICAL, RHINOLOGICAL AND OTOLOGICAL SOCIETY, INC

President Dr Gordon Hoople 1100 E Genesee St., Syracuse 10 N Y
President Elect Dr Theo E Walsh 640 So Kingshighway, St. Louis 10 Mo
Secretary Dr C Stewart Nash 700 Medical Arts Bldg Rochester 7, N Y
Place The Homstead Hot Springs Va., March, 1959

AMERICAN MEDICAL ASSOCIATION, SECTION ON LARYNGOLOGY, OTOLOGY AND RHINOLOGY

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AMERICAN OTOLOGICAL SOCIETY, INC

President Dr Moses Lurie, Boston, Mass
President Elect Dr R C Martin
Secretary Dr Lawrence R Boies, University Hospitals, Minneapolis 14, Minn
Place The Homestead, Hot Springs, Va., 1959

AMERICAN OTORHINOLOGIC SOCIETY FOR THE ADVANCEMENT OF PLASTIC AND RECONSTRUCTIVE SURGERY

President Dr Joseph Gilbert, 111 E 61st St, New York, N Y
Vice-President Dr Kenneth Hinderer, 402 Medical Arts Bldg, Pittsburgh, Pa.
Secretary Dr Louis Joel Feit, 66 Park Ave, New York 16, N Y
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AMERICAN RHINOLOGIC SOCIETY

President Dr Russell I Williams, 408 Hynds Bldg, Cheyenne, Wyo
Secretary Dr Robert M Hansen 1735 No Wheeler Ave, Portland, Ore
Annual Clinical Session Illinois Masonic Hospital, Chicago, Ill, October, 1958
Annual Meeting October, 1958, Chicago, Ill (Definite time and place to be announced later)

AMERICAN SOCIETY OF FACIAL PLASTIC SURGERY

President Dr Trent W Smith, 327 East State St., Columbus 15 Ohio
Secretary Dr Samuel M Bloom, 123 East 83 St, New York 28, N Y
Meeting New York, July 16, 1958, December 3, 1958, place to be announced

AMERICAN SOCIETY OF OPHTHALMOLOGIC AND OTOLARYNGOLOGIC ALLERGY

President Dr Joseph W Hampsey, Grant Bldg, Pittsburgh 19, Pa.
Secretary Treasurer Dr Daniel S DeStio, 121 S Highland Ave, Pittsburgh 6, Pa.
Annual Meeting Palmer House, Chicago, Ill October 16 17, 1958

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Meetings Twice every month, first and third Thursday 8 30 P M

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Secretary-Treasurer Dr Fletcher Austin, 700 No Michigan Ave, Chicago 11 Ill
Meeting First Monday of each Month October through May

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Secretary-Treasurer Dr Carl S McLemore, 1217 Kuhl Ave , Orlando, Fla.

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Meeting

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INTERNATIONAL BRONCHOESOPHAGOLOGICAL SOCIETY

President Dr Jo Ono, Tokyo, Japan.
Secretary Dr Chevalier L Jackson, 3401 N Broad St , Philadephia 40 Pa., U S A.
Meeting Seventh International Congress of Bronchoesophagology, Kyoto, Japan, September, 1958

KANSAS CITY SOCIETY OF OTOLARYNGOLOGY AND OPHTHALMOLOGY

President Dr Clarence H. Steele
President Elect Dr Dick H. Underwood
Secretary Dr James T Robison, 4620 J C Nichols Parkway, Kansas City, Mo
Meeting Third Thursday of November January February and April

LOS ANGELES SOCIETY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY

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Secretary Treasurer Dr Max E Pohlman.
Chairman of Ophthalmology Section Dr Richard Kratz
Secretary of Ophthalmology Section Dr Carrall A. McCoy
Chairman of Otolaryngology Section Dr Howard G Gottschalk.
Secretary of Otolaryngology Section Dr Robert W Godwin.
Place Los Angeles County Medical Association Bldg, 1925 Wilshire Blvd, Los Angeles Calif
Time 6 30 P M last Monday of each month from September to June, inclusive—Otolaryngology Section 6 30 first Thursday of each month from September to June, inclusive—Ophthalmology Section.

LOUISIANA MISSISSIPPI OPHTHALMOLOGICAL AND OTOLARYNGOLOGICAL SOCIETY

President Dr Fred D Hollowell Lamar Life Bldg Jackson, Miss
Secretary Dr Edley H. Jones, 1301 Washington St. Vicksburg Miss
Meeting Edgewater Gulf Hotel Edgewater Park, Miss May 15-16 1959

MEMPHIS SOCIETY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY

Chairman Members serve as chairmen in alphabetical order monthly
Secretary-Treasurer Dr Roland H Myers, 1720 Exchange Bldg, Memphis, Tenn.
Assistant Secretary-Treasurer Dr William F Murrah, Jr, Exchange Bldg., Memphis Tenn.
Meeting Second Tuesday in each month at 8 00 p.m. at Memphis Eye Nose and Throat Hospital.

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Meeting Palmer House, Chicago, Ill

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Meeting

PAN AMERICAN ASSOCIATION OF OTO-RHINO LARYNGOLOGY AND BRONCHO-ESOPHAGOLOGY

President Dr Jose Gros, Havana, Cuba
Executive Secretary Dr Chevalier L Jackson, 3401 N Broad St., Philadelphia 40, Pa., U S A.
Meeting Sixth Pan American Congress of Oto Rhino-Laryngology and Broncho-Esophagology
Time and Place Brazil, 1958

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Place Army and Navy Club, Washington, D C

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STAPES OPERABILITY

Pathological Indications for Mobilization and Fenestration Surgery *†

J BROWN FARRIOR, M D ,

Tampa, Fla

In recent years we, as otologists, have learned many techniques for mobilization of the stapes in otosclerotic deafness Through one technique or another, it is now possible to mobilize a very high percentage of stapes Even after complete mobilization many of these will show a prompt recurrence of the deafness, because the pathological involvement was beyond the limits of stapes surgery As otologists we must learn not only the new techniques, but also their pathological limitations

Initially the technique of the stapes mobilization operation was indirect, that is, all pressures were applied to or through the head and neck of the stapes With this basic indirect technique, primary hearing improvement was obtained in about one-third of the cases, and when mobilization was technically complete, a high percentage of these maintained the hearing improvement With this indirect approach, we were mobilizing only those cases with limited pathological involvement, and these pathologically favorable cases tended to maintain their hearing improvement

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*Presented at the meeting of the Southern Section of American Laryngological Rhinological and Otological Society Inc. Memphis Tenn Jan 25 1958

†From Southern Foundation of Better Hearing Tampa Fla.

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Today the indirect approach is largely replaced by a direct surgical attack upon the footplate and the disease process itself Now the percentage of primary results has almost trebled, and is no longer limited by the strength of the crura, it is limited only by the boldness of the surgeon and a few completely inoperable stapes With chisel, picks and drills, the enthusiastic surgeon can temporarily mobilize most all stapes The primary results have increased, but the incidence of re-fixation has also multiplied with this direct attack on the extensively diseased stapes

If we are to continue to attack these extensively diseased stapes and reduce the incidence of re-fixation, we must proceed with excavation of the footplate and the application of prosthetic crura (Shea[1]), or we must declare more stapes inoperable Extensive oval window surgery may prove to be worth while, and is worthy of investigation It may prove to be applicable in certain types of pathological involvement, but there will remain specific pathological limitations

As we approach the pathological limitations of stapes surgery (indirect, direct, or oval window) we arrive at the pathological indications for the fenestration operation The fenestration operation has received a wide variety of reputations By the early 1950s it had reached a standard of perfection that produced a very high percentage of grateful and happy patients, a percentage greater than the ear surgery of 1957, however, some still judge the fenestration operation by its reputation of the early 1940s and regard it only as surgery of the last resort The fenestration operation is a highly reliable and accurately predictable operation, it remains the master surgical procedure which will restore worthwhile and lasting hearing improvement in a high percentage of suitable cases which are beyond the pathological limits of stapes and oval window surgery

The thesis of this study is that there are specific pathological indications for stapes surgery and specific pathological indications for fenestration surgery, also, that in stapes surgery there are specific pathological indications for the variations of the indirect and direct surgical approach To date otologists have used the chance approach to stapes surgery with the attitude of try, and try again, and some have tended to exclude the fenestration operation until the stapes mobilization has failed, and failed again Although we can never draw fine lines of differentiation on the operability of the stapes, it is my hope that an appreciation of the tremendous variations in the pathology of the stapes will lead to an understanding of the broader classifications of the favorable, unfavorable and inoperable stapes

A stapes is called favorable when the anatomy and pathology lend themselves to stapes surgery, and when the prognosis for maintained mobilization and hearing improvement is good

A stapes is unfavorable when it can be mobilized but the pathology indicates that the prognosis is guarded A stapes is inoperable when pathologically it cannot be mobilized or, if mobilized, refixation is almost certain The classification is a surgical opinion of the existing anatomy and pathology, and is not dependent upon technical success or failure

At the meeting of the American Academy of Ophthalmology and Otolaryngology in October, 1957, I presented preliminary opinions and classifications of the anatomy and pathology of the stapes and their effect upon the operability of the stapes We are on the threshold of defining the operability of the stapes, based upon the anatomical variations and the type of pathological involvement This work is here republished with corrections, illustrations, additions and elaborations (Farrior 2a and b)

STAPES OPERABILITY

The operability of the stapes is dependent upon the type of anatomical development and the pathological involvement Anatomically the footplate of the stapes may be superficial or in a very deep niche The first is most favorable for mobilization surgery, while with the deeply placed footplate the crura tend to become involved in the otosclerotic process, making the stapes either unfavorable or inoperable for mobilization surgery

Pathologically the otosclerosis may involve only the anterior edge of the footplate, or it may involve varying degrees of the footplate, crura, or even the head and neck of the stapes The simple footplate involvement is very favorable for mobilization surgery, while the complete otosclerotic involvement is inoperable, and is a positive indication for the fenestration operation

CHART I

Anatomically variations in the depth of the footplate and angulation of the crura alter the operability of the stapes (see Figs 1, 2 3) A superficial footplate with upright crura is the most favorable anatomical development for mobilization surgery

A.—Depth of the Footplate of Stapes	Operability (Prognosis)
1 Superficial	Favorable
2 Moderately superficial	Less Favorable
3 Moderately deep	Unfavorable
4 Deep	Unfavorable

B—Angulation of Crura	Operability (Prognosis)
1 Upright	Most Favorable
2 Downward tilt (free)	Less Favorable
3 Downward tilt (fixed)	Unfavorable
4 Upward tilt	Less Favorable

C—Strength of Crura	Operability (Prognosis)
1 Weak Crura	Vulnerable
2 Medium Crura	Mod Vulnerable
3 Strong Crura	Invulnerable
4 Atrophic Crura	Inoperable Footplate

The purpose of this presentation is to demonstrate the varying anatomy and pathology of the stapes and, in so doing, to define the operability of the stapes

ANATOMICAL VARIABLES

The position of the footplate may alter the operability of the stapes (see Chart I)

If the footplate of the stapes is very superficially placed, the otosclerotic involvement will usually be thin, and there is no anatomical tendency for the otosclerosis to involve the crura (see Fig 1) If, on the other hand, the footplate of the stapes is in a deep niche, the crura tend to become tilted downward and thus easily contact the inferior lip of the

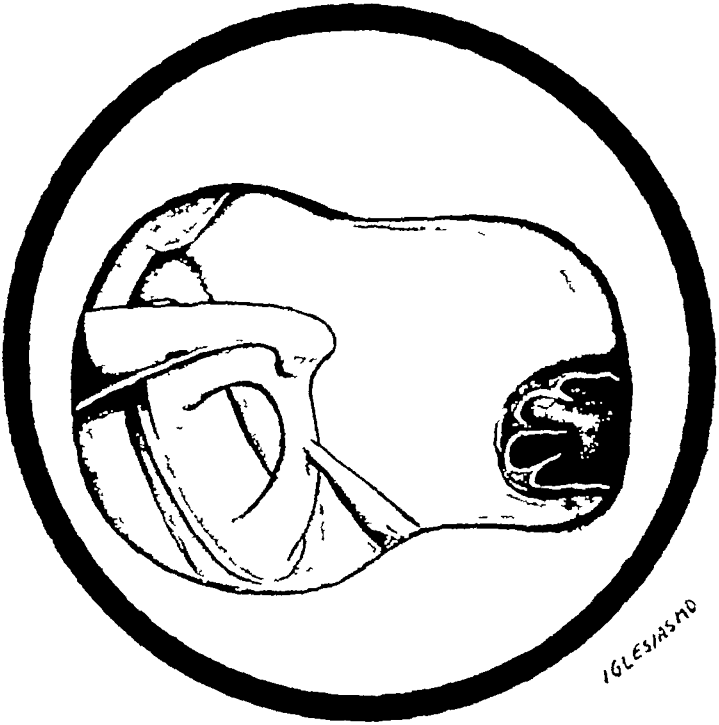

Fig 1 Anatomically when the footplate of the stapes is superficially placed and the crura are upright the otosclerosis tends to remain localized to the level of the footplate This figure illustrates a superficially placed footplate with upright crura and a small focus of circumscribed anterior footplate otosclerosis (see Chart I) For stapes surgery this is the most favorable anatomical development and pathological involvement.

oval window This predisposes toward otosclerotic involvement of one or both crura (see Fig 2), or complete otosclerotic filling of the oval window niche With a deep footplate, the crura will occasionally tilt upward to contact the Fallopian canal (see Fig 3) As the pathology progresses the operability becomes unfavorable to inoperable

The strength of the crura does not greatly alter the operability of the stapes with the direct surgical attack upon the footplate True, if the crura are weak or friable this predisposes toward their fracture, but too much pressure on the crura is a surgical error rather than the cause of inoperability

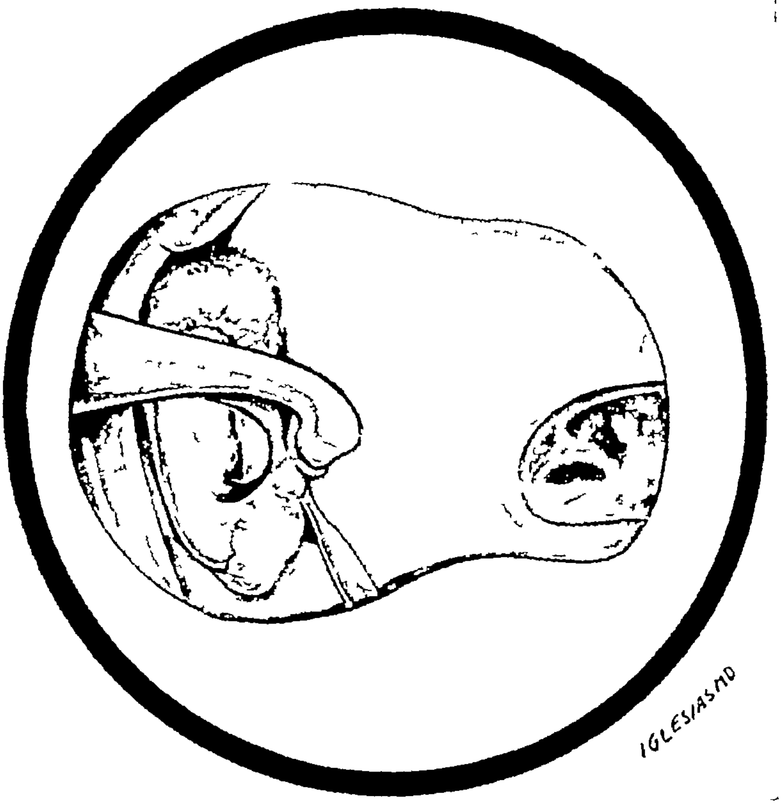

Fig 2 Anatomically when the footplate of the stapes is deeply placed in the oval window niche the crura tend to tilt downward and contact the inferior lip of the oval window niche This contact predisposes toward otosclerotic fixation of the crura and such crural otosclerosis alters the operability of the stapes (See Chart I) As re-fixation is prompt bi-crural otosclerosis is pathologically beyond the operable limits of manipulative operations on the total stapes

Atrophy of the crura is generally associated with complete footplate otosclerosis which is in itself inoperable Translucent red crura are the most friable while white crura will withstand the greatest amount of manipulation As others may wish to include a classification of crural strength, this is included in Chart I

PATHOLOGICAL VARIABLES

I LOCATION OF OTOSCLEROSIS

The location and character of the otosclerosis greatly alters

CHART II —PATHOLOGICAL VARIABLES

The location and extent of the otosclerosis are the most important single factors in determining the operability of the stapes Originally I believed that the per cent of involvement of the footplate was the most important factor At the present time I believe that the thickness of the otosclerosis and involvement of the crura have the greatest effect on operability

A. Location of Otosclerosis	Operability
I Type of Otosclerosis	
1 Circumscribed	Favorable (see Fig 6c)
2 Diffuse	Unfavorable (see Fig 6d)
II Footplate Otosclerosis (Fig 4a b c d)	
1 None	Favorable
2 Anterior Footplate	Favorable
3 Posterior Footplate	Favorable
4 Superior Marginal	Unfavorable
5 Inferior Marginal	Unfavorable
6 1/4 Footplate Involved	Favorable
7 2/4 Footplate Involved	Less Favorable
8 3/4 Footplate Involved	Unfavorable (Thick)
9 Complete Footplate (thin)	Favorable (thin) (see Fig 6a)
10 Complete Footplate (thick)	Inoperable (thick) (see Fig 6b)
III Crural Otosclerosis (see Fig 5a b c d)	
1 None	Favorable
2 Anterior Crus	Favorable
3 Posterior Crus	Unfavorable
4 Bicrural Anterior and Posterior Crura	Inoperable
5 Apical	Inoperable
6 Cervical	Inoperable
IV Round Window Otosclerosis	
1 No Otosclerosis	Favorable
2 Marginal Without Closure	Favorable
3 Partial Closure	Unfavorable
4 Complete Closure	Inoperable for Either Mobilization or Fenestration

the operability of the stapes (see Chart II) Otosclerosis, which alters operability, may involve the footplate of the stapes, the crura of the stapes, the neck of the stapes or the round window

The two basic types of otosclerosis are circumscribed and diffuse—Fowler[3] Circumscribed otosclerosis is in general the type which responds best to mobilization surgery, providing the location and anatomy are favorable Stapes surgery is rarely of lasting value in diffuse otosclerosis which extends over the entire promontory Eventually we may learn that circumscribed and diffuse otosclerosis are separate diseases

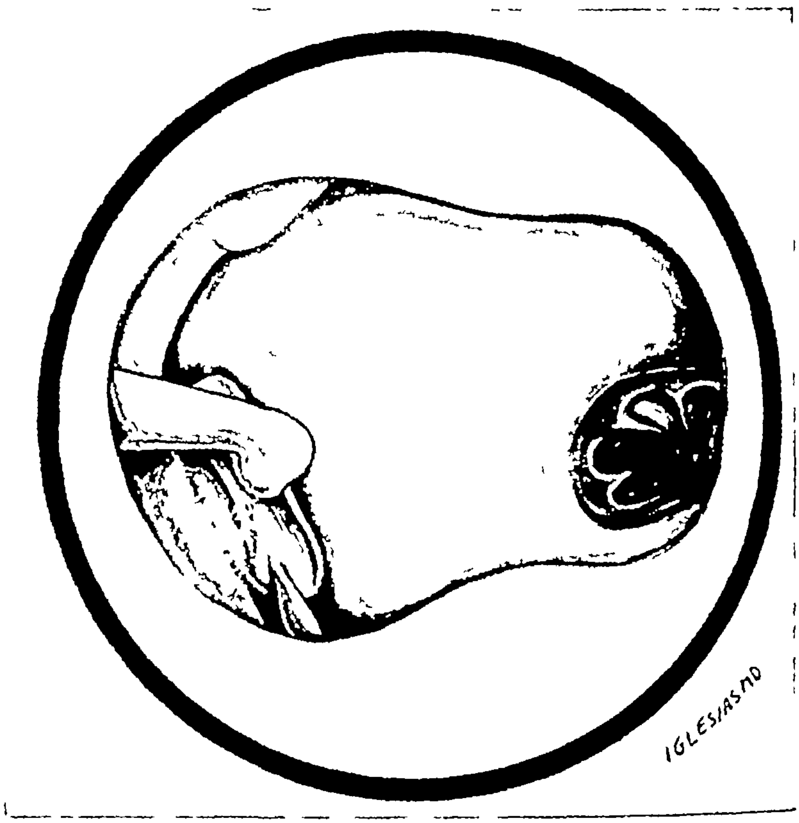

Fig 3 Anatomically when the footplate of the stapes is deeply placed in the oval window niche the crura will sometimes tilt upward to contact the fallopian canal This contact predisposes toward otosclerosis or post-mobilization scar fixation between the crura and the fallopian canal (See Chart I)

From clinical experience, it seems that circumscribed anterior footplate otosclerosis is most favorable for mobilization surgery (see Fig 4a) Posterior footplate otosclerosis is equally favorable, but occurs less frequently (see Fig 4b) Superior marginal (see Fig 4c), and inferior marginal (see Fig 4d), are less favorable, for they tend to involve the sides of the crura The degree of involvement of the footplate is significant, and its influence upon operability is intimately associated with the thickness of the otosclerosis and crural involvements Complete otosclerosis of the footplate may still be operable as long as the annulus of the footplate remains well defined and there is no crural involvement, this

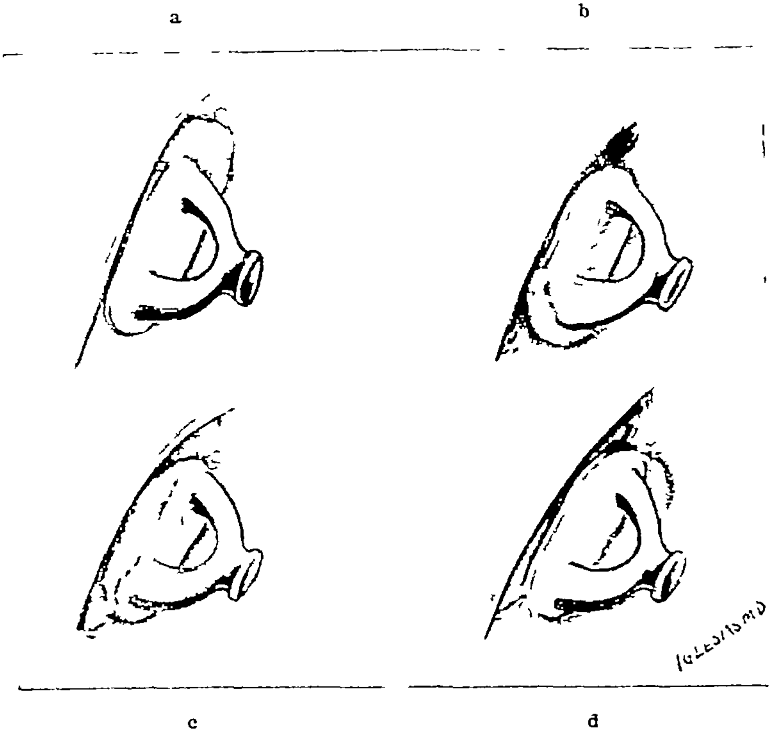

Fig 4 Footplate otosclerosis Circumscribed footplate otosclerosis is most favorable for stapes mobilization surgery The otosclerosis tends to remain at the level of the footplate when the footplate is superficial and the crura do not contact the margins of the oval window niche Anterior footplate (see Fig 4b) and superior marginal (see Fig 4c) otosclerosis are present occasionally Inferior marginal (see Fig 4d) otosclerosis is frequent, and is usually a continuation posteriorly of anterior footplate otosclerosis (see Chart II)

is found in thin, white otosclerosis (see Fig 6a) When the otosclerosis is thick enough to obliterate the annulus of the footplate the stapes becomes inoperable (see Fig 6b)

Otosclerosis may involve one or both crura, as previously stated, crural otosclerosis is most likely to occur in the deeply placed footplate with tilted crura Anterior crural otosclerosis (see Fig 5a) is favorable for mobilization surgery, but re-fixation is likely to occur unless an anterior-crurotomy is performed—Fowler[4] Posterior crural otosclerosis (see Fig 5b) has not been found as an isolated patholog-

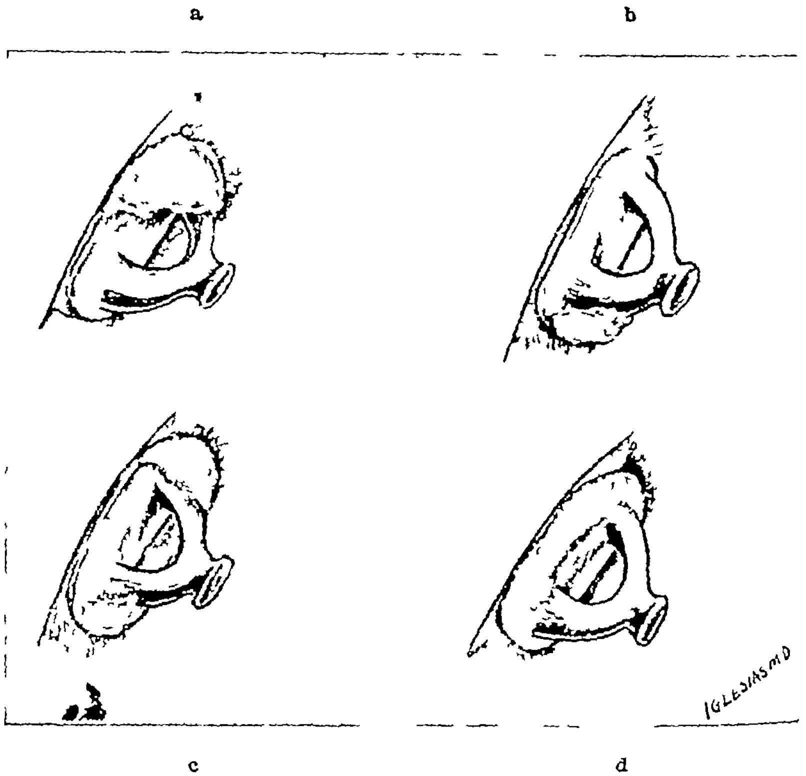

Fig 5 Crural otosclerosis Crural involvement by the otosclerotic process greatly alters the operability of the stapes Anterior crural (see Fig 5a) otosclerosis is frequent and is an indication for anterior crurotomy and posterior footplate mobilization Posterior crural (see Fig 5b) otosclerosis has not been found as an isolated entity Bi-crural otosclerosis is found with some frequency and is associated with inferior marginal (see Fig 5c) or superior marginal (see Fig 5d) otosclerosis in a deeply placed footplate

ical entity, but if it does, I should consider a posterior-crurotomy

Bi-crural otosclerosis has occurred in numerous instances, most frequently with inferior marginal otosclerosis (see Fig 5c), and occasionally in superior marginal otosclerosis (see Fig 5d) In each instance there has been re-fixation of the stapes after successful complete mobilization It is my present opinion that bi-crural otosclerosis is beyond the limits of present day mobilization surgery, and in the suitable candidate is a clear-cut indication for the fenestration operation In some instances the otosclerotic fixation has extended up the crura to involve the apex of the two crura and the neck

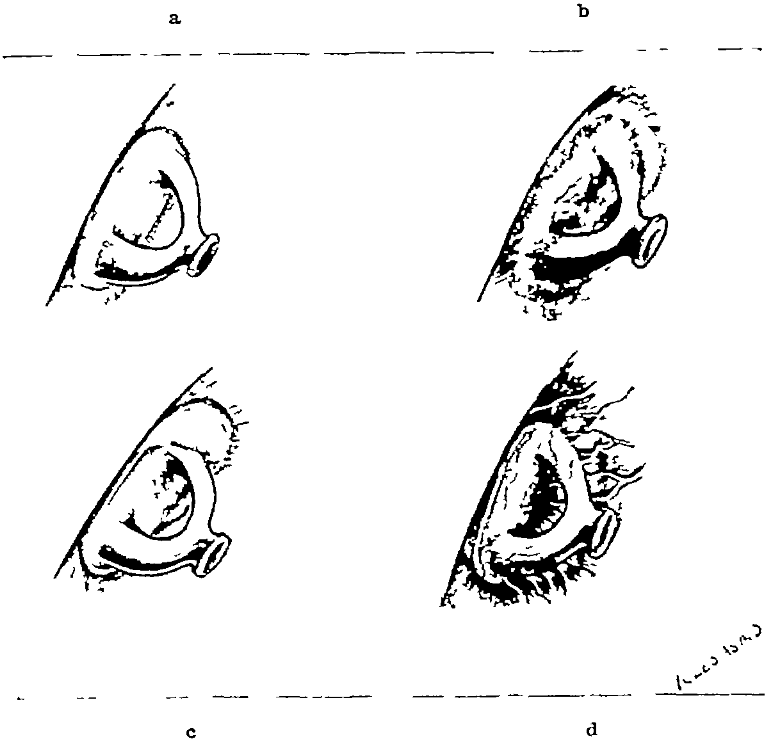

Fig 6 Character of otosclerosis. The thickness and the color (vascularity) of the otosclerosis alter the operability of the stapes Complete footplate otosclerosis may still be operable when thin the annulus is well defined and the crura are not involved (see Fig 6a) however when the otosclerosis of the complete footplate and oval window niche becomes thick enough to obliterate the annulus (see Fig 6b) of the footplate the stapes is then inoperable.

Circumscribed white avascular otosclerosis (see Fig 6c) is most favorable for stapes surgery while diffuse red vascular otosclerosis (see Fig 6d) will usually re-fix, even after complete mobilization.

of the stapes Such apical and cervical otosclerosis are beyond the limits of present day mobilization surgery

Bi-crural otosclerosis, with an area of normal or nearly normal footplate, may prove to be the type of pathology that will respond to mobilization or excavation of the footplate with or without replacing the crura (re-crural or de-crural)

Complete otosclerotic closure of the round window is a contra-indication to mobilization or fenestration surgery With a partial or almost complete closure of the round window the patient can still obtain maximum benefits from surgery, however, the long term prognosis is not favorable Round window closure has occurred independent of stapes fixation, however, in most instances there is associated unfavorable or inoperable pathology of the stapes (diffuse otosclerosis, see Fig 6d)

CHART III—PATHOLOGICAL VARIABLES

The otosclerosis may be thin or thick, white or red, depending upon the activity and vascularity Circumscribed thin white otosclerosis of the anterior footplate is most favorable for stapes surgery, while diffuse thick red vascular otosclerosis is inoperable

Character of Otosclerosis	Operability
V Thickness of Otosclerosis of Stapes and Oval Window (see Fig 6a and b)	
1 Very Thin	Favorable
2 Thin	Favorable
3 Moderately Thick	Unfavorable
4 Thick	Inoperable
VI Color of Otosclerosis (see Fig 6c and d)	
1 White	Favorable
2 Nearly White	Favorable
3 Pink	Unfavorable
4 Red	Inoperable

V *Thickness of Oval Window Otosclerosis of the Stapes*

The thickness of the otosclerosis alters the operability of the stapes (see Charts III-V) Thin circumscribed otosclerosis is most favorable for mobilization surgery, while thick diffuse otosclerosis is the most unfavorable As previously stated, as long as the margin of the annulus of the footplate is not obliterated by the disease and the crura are free, the operability is reasonably favorable (see Fig 6a), however, when the otosclerosis thickens to obliterate the annulus or fill the oval window, the stapes becomes inoperable (see Fig 6b) This is most frequent in diffuse otosclerosis In such cases, there is no need to jeopardize inner ear function with excessive footplate surgery when the existing pathology is beyond the limits of stapes surgery, present or future

VI *Color of Otosclerosis*

The operability of the stapes varies with the color of the otosclerosis (see Charts III-VI) White (avascular) otosclerosis (see Fig 6c) is most favorable for lasting results in mobilization surgery, while in red (vascular) otosclerosis (see Fig 6d) mobilization can be accomplished, but there is almost uniform re-fixation The vascularity and operability may vary from white, to off-white, to pink, to red Again, if on a pathological basis the prognosis is most unfavorable, it is absurd to persist in an operation where at best there will be a transient improvement, and where excessive surgery might result in cochlear damage

THE AUDIOGRAM AND THE LOCATION OF THE OTOSCLEROSIS

Worthy of note is the effect of otosclerotic involvement upon the audiogram

Anterior footplate and anterior crural otosclerosis tend to present a flat or ascending air conduction audiogram with nearly normal bone conduction As the fixation of the footplate progresses the Carhart[5] notch develops It has long been taught that loss of high tones indicates complete footplate fixation I have seen a number of cases with flat audiograms and complete footplate fixation, but the flat audiogram persists only as long as good strong free crura are transmitting vibrations to the fixed footplate When the sides of both crura become fixed, and they are no longer capable of transmitting to the footplate, then there is loss of the high tones (2,000, 4,000 and 8,000), and progression of the Carhart notch, with diminution of the air bone gap at 2,000 This has occurred when crural fixation was associated with complete footplate fixation, but, of greater significance is the fact that this has occurred, in combined marginal and bi-crural otosclerosis when the opposite half of the footplate was a perfectly normal translucent blue, that is, incomplete footplate fixation but complete loss of crural transmission Subject to subsequent statistical study, it is my present clinical opinion that the audiogram tends to remain flat and speech discrimination good as long as strong free crura are transmitting vibrations to the footplate, even though the footplate itself is completely fixed dow the patient can still obtain maximum benefits from surgery, however, the long term prognosis is not favorable Round window closure has occurred independent of stapes fixation, however, in most instances there is associated unfavorable or inoperable pathology of the stapes (diffuse otosclerosis, see Fig 6d)

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This association of the type of otosclerotic involvement and the high tone loss does not apply to an independent nerve deafness—Farrior[6] For example, when there is an independent nerve loss for the high tones from one cause (acoustic trauma, presbycusis, etc), and the patient has otosclerosis, causing the loss of low tones, the association of high tone loss with progression is not true This type of independent high tone loss does not indicate alteration in the operability of the stapes

CHART IV —MISCELLANEOUS PATHOLOGY

Stapes surgery has revealed a never ending list of miscellaneous lesions which will produce or complicate an otosclerotic type of deafness This classification is presented for the accumulation of statistical data

VII —Mucous Membrane Webs
VIII —Fibrous Adhesions
IX —Abnormalities of Footplate
X.—Abnormalities of Anterior Crus
XI —Abnormalities of Posterior Crus
XII —Abnormalities of Stapedius
XIII —Abnormalities of Incus
XIV —Abnormalities of Malleus
XV —Systemic Diseases

The cases of combined oval and round window closure have been severely deaf, and audiometrically have shown only a little residual air conduction and bone conduction for the lower tone frequencies, however, such an audiogram does not always indicate round window closure

MISCELLANEOUS PATHOLOGY

By clinical observation under the operating microscope we are discovering a never ending list of miscellaneous lesions (see Chart IV), which will simulate the otosclerotic type of deafness or will alter the operability of the stapes In the past our knowledge of the variables of otosclerosis has been limited to a relatively small number of autopsy specimens—Fowler,[3] Ruedi,[7] Guild,[8 9 10] Eggston and Wolfe,[11] Lindsey,[12] and others Today, with the operating microscope, and photographic slides of the surgical pathology, the opportunity to learn about the pathology and audiology of otosclerosis is greatly increased

As otologists learn the detail of the pathology of otosclerosis we add to this never ending list of miscellaneous pathological entities and learn the significance of minute variations in middle ear anatomy and pathology Mucous membrane webs over and around the stapes are a frequent occurrence, and do not greatly alter the operability of the stapes I used to destroy these mucous membrane webs to obtain greater visibility of the stapes, however, I believe this results in greater post-operative scar formation, and at present prefer to operate through or around these webs Dense scar tissue does alter the operability of the stapes, the operability varying with the amount and location of the scar tissue, where possible, I remove or shunt these fibrous adhesions, but believe that adhesions tend to recur as they do elsewhere in the body

CHART V —PATHOLOGICAL COMBINATIONS

The operability of the stapes is determined by the combination of the anatomical and pathological variables The following are in general the order of frequency of these combinations

1 Anterior footplate.
2 Anterior footplate anterior crural
3 Anterior footplate anterior crural inferior marginal
4 Anterior footplate anterior crural inferior marginal posterior crural
5 Anterior footplate anterior crural, superior marginal
6 Anterior footplate anterior crural superior marginal, posterior crural.
7 Complete footplate thin
8 Complete footplate thick.

Schuknecht has reported a case of fixation of the stapedius tendon Odess reports a case of malleable incus All of us have seen fixed ossicles in congenital deformities, infections and in arthritis I have one case with large blue footplate with apparent congenital absence of the annulus of the footplate This list of miscellaneous pathology will never be complete, and all oddities should be reported The list of miscellaneous pathology is presented as a basic classification, to which unusual cases can be added

ACCURATE DIAGNOSIS AND CLASSIFICATION

Any statistical reporting of results of mobilization surgery

This association of the type of otosclerotic involvement and the high tone loss does not apply to an independent nerve deafness—Farrior [6] For example, when there is an independent nerve loss for the high tones from one cause (acoustic trauma, presbycusis, etc), and the patient has otosclerosis, causing the loss of low tones, the association of high tone loss with progression is not true This type of independent high tone loss does not indicate alteration in the operability of the stapes

CHART IV—MISCELLANEOUS PATHOLOGY

Stapes surgery has revealed a never ending list of miscellaneous lesions which will produce or complicate an otosclerotic type of deafness This classification is presented for the accumulation of statistical data

VII—Mucous Membrane Webs
VIII—Fibrous Adhesions
IX.—Abnormalities of Footplate
X—Abnormalities of Anterior Crus
XI—Abnormalities of Posterior Crus
XII—Abnormalities of Stapedius
XIII—Abnormalities of Incus
XIV—Abnormalities of Malleus
XV—Systemic Diseases

The cases of combined oval and round window closure have been severely deaf, and audiometrically have shown only a little residual air conduction and bone conduction for the lower tone frequencies, however, such an audiogram does not always indicate round window closure

MISCELLANEOUS PATHOLOGY

By clinical observation under the operating microscope we are discovering a never ending list of miscellaneous lesions (see Chart IV), which will simulate the otosclerotic type of deafness or will alter the operability of the stapes In the past our knowledge of the variables of otosclerosis has been limited to a relatively small number of autopsy specimens—Fowler,[3] Ruedi,[7] Guild,[8 9 10] Eggston and Wolfe,[11] Lindsey,[12] and others Today, with the operating microscope, and photographic slides of the surgical pathology, the opportunity to learn about the pathology and audiology of otosclerosis is greatly increased in the three dimensional photographs and, finally, the clinical comments on surgical technique and surgical judgment

The 3-D photographs are taken from the position of the operator, sitting behind the patient looking into the middle ear The incus is the key anatomical landmark, the pathology will be described in relation to the incus first, anterior to the incus (around the anterior crus and footplate), and second, posterior to the incus from superior to inferior (left to right) For clarity of presentation all ears are presented as right ears

OUTLINE OF ILLUSTRATIVE CASES

Introductory Cases Case 1—Ideal Pathology, Case 2—Inoperable Otosclerosis, Case 3—Bilateral Otosclerosis, Case 4—Fibrous Adhesions

Anatomical Positions Case 5—Downward Tilt, Case 6—Upward Tilt, Case 7—Upward Tilt with Fixation, Case 8—Fallopian Canal Otosclerosis

Aural Otosclerosis Case 9—Anterior Crural Otosclerosis, Case 10—Superior Bi-crural Otosclerosis, Case 11—Inferior Bi-crural Otosclerosis

Character of Otosclerosis Case 12—Pink Otosclerosis, Case 13—Thin complete footplate otosclerosis, Case 14—Thick complete footplate otosclerosis, Case 15—Inoperable Otosclerosis oval and round window

Post-Mobilization Pathology Case 16—Post-mobilization fibrous, Case 17—Probable technical mobilization failure, Case 18—Primary stapes failure from unfavorable pathology, Case 19—Primary stapes failure, inoperable thick footplate

Fenestration Continuity Case 20—Footplate mobilization attempted (thick footplate), Case 21—Unfavorable stapes pathology

INTRODUCTORY CASES

Case 1 SR—282 F —Ideal Pathology

Diagnosis

1 Otosclerosis circumscribed anterior footplate (1/4) thin white favorable

should be based upon the type of anatomical development and the type of pathology present. Only by such a basic classification can we learn which operations, and which techniques, will give lasting results in individual pathological circumstances. This classification of the anatomy, pathology of otosclerosis and miscellaneous pathology is presented as we begin to define the operability of the stapes; degrees of involvement are outlined for coding statistics. The variables are many, and the operability is determined by the combinations of the anatomical and pathological variables (see Chart V). This classification should be changeable; other contributors should make suggestions and corrections, and the opinions on operability of the stapes will naturally vary from year to year as we learn new techniques and new limitations. Certainly the diagnosis "otosclerosis" alone is inadequate for study and future reference. The diagnosis should include a description of the anatomical and pathological findings, and should be complete as:

1. Otosclerosis, circumscribed, thin, white, anterior footplate, 3/4 blue, inferior marginal, favorable.

2. Stapes, fixed, deep, downward tilt.

3. Round window, normal, webs.

4. Hearing, flat audiogram, 45 db. loss, air-bone gap 35, good speech discrimination, good candidate.

ILLUSTRATIVE CASES

This study is based upon a series of three-dimensional photographs of the surgical pathology of the stapes. More than 850 photographs have been taken in a series of 147 consecutive operations for otosclerosis. The experiences are based upon a series of 326 mobilizations and 724 fenestrations—a total of more than 1,000 operations. The pathology found in selected cases is herein described in detail to illustrate the effect of the variable pathology on the operability of the stapes.

With each illustrative case will be given, first, the detailed diagnosis; second, the description of the surgical pathology

Comments

In bilateral otosclerosis the anatomy and pathology of the stapes are similar in type, though they may vary in degree

In this minimal pathology mobilization was attempted by indirect pressure on the incus, however, when the posterior crus began to redden, indicating an impending fracture, a direct attack was made upon the anterior footplate and complete footplate mobilization obtained

Case 4 SR—254 Von V—Adhesions and Otosclerosis

Diagnosis

1 Otosclerosis, circumscribed, thin white anterior footplate with thick fibrous adhesions
2 Stapes fixed upright strong crura.
3 Round window normal

Description of 3 D Photograph

This is a favorable stapes complicated by white fibrous adhesions

A Anterior to the incus

1. Thin, white otosclerosis fixes the anterior margin of the foot plate.

P Posterior to the incus, from superior to inferior are

1 The normal Fallopian canal
2 An area of superficial blue footplate
3 The anterior portion of the footplate is covered by white fibrous adhesions, the posterior 1/2 of the footplate is normal blue
4 The posterior crus is strong and upright
5 The round window is normal

Comments

Fibrous adhesions limit the operability of the stapes

In this case with thin, white anterior footplate otosclerosis and anterior footplate adhesions there was prompt re-fixation of the stapes Subsequently, an anterior crurotomy and posterior footplate mobilization were performed, giving a lasting result

ANATOMICAL POSITIONS

Case 5 SL—255-Y—Downward Tilt.

Diagnosis

1 Otosclerosis, circumscribed, white anterior footplate footplate 3/4 blue
2 Stapes deep footplate downward tilt of crura no posterior crural fixation unfavorable
3 Round window normal

2 Stapes, fixed, superficial upright
3 *Round window normal*

Description of 3 D Photogroph (Fig 1)

A Anterior to the incus there is an area of thin white footplate otosclerosis, the otosclerosis does not involve the anterior crus

P Posterior to the incus, from superior to inferior, are

1 The normal Fallopian canal
2 The normal translucent easily seen superficial footplate of the stapes
3 The upright free strong posterior crus of the stapes
4 The stapedius tendon
5 The normal round window

Comments

This stapes, with limited pathological involvement of the footplate, was mobilized with the indirect approach by pressure on the incus The result was lasting

Case 2 SL—214-MM—Inoperable Diffuse Otosclerosis

Diagnosis

1 Otosclerosis, diffuse red footplate (3/4), bi crural inoperable
2 Stapes fixed, deep, downward tilt
3 Round window closing nearly complete

Description of 3 D Photograph (more than Fig 6d)

A. Anterior to the incus

1 Red vascular otosclerosis involves the entire anterior crus to the apex of the crura
2 The promontory is covered with red vascular otosclerosis

P Posterior to the incus, from superior to inferior are

1 The normal Fallopian canal
2 A very deep footplate of the stapes, almost invisible
3 There is a downward tilt of the posterior crus with posterior crural otosclerosis
4 There is almost complete closure of the round window

Comments

Mobilization was easily accomplished by pressure on the incus, however, in thick, red bi-crural otosclerosis of a deep stapes with downward tilt of the crura, the mobilization was of transient value In almost complete round window closure in active otosclerosis, fenestration would be of transient value, and I have advised against fenestration surgery because of the emotional instability of the patient

Case 3 SL—283 F—Bilateral Otosclerosis

Diagnosis and description

This is the left ear of Case 1 the diagnosis anatomy and pathology are almost identical (see Fig 1)

Comments

In bilateral otosclerosis the anatomy and pathology of the stapes are similar in type, though they may vary in degree

In this minimal pathology mobilization was attempted by indirect pressure on the incus, however, when the posterior crus began to redden, indicating an impending fracture, a direct attack was made upon the anterior footplate and complete footplate mobilization obtained

Case 4 SR—254 Von V —Adhesions and Otosclerosis

Diagnosis

1 Otosclerosis circumscribed, thin, white anterior footplate with thick fibrous adhesions
2 Stapes fixed, upright strong crura.
3 Round window normal

Description of 3 D Photograph

This is a favorable stapes, complicated by white fibrous adhesions

A. Anterior to the incus
  1. Thin, white otosclerosis fixes the anterior margin of the foot plate

P Posterior to the incus from superior to inferior are
  1 The normal Fallopian canal.
  2 An area of superficial blue footplate
  3 The anterior portion of the footplate is covered by white fibrous adhesions the posterior 1/2 of the footplate is normal blue.
  4 The posterior crus is strong and upright.
  5 The round window is normal

Comments

Fibrous adhesions limit the operability of the stapes

In this case with thin, white anterior footplate otosclerosis and anterior footplate adhesions there was prompt re-fixation of the stapes Subsequently, an anterior cruiotomy and posterior footplate mobilization were performed, giving a lasting result

ANATOMICAL POSITIONS

Case 5 SL—255-N —Downward Tilt.

Diagnosis

1 Otosclerosis circumscribed, white anterior footplate footplate 3/4 blue
2 Stapes deep footplate downward tilt of crura, no posterior crural fixation unfavorable
3 Round window normal

This is an operable but unfavorable stapes with a deep footplate and *downward tilt of the crura.*

Description of 3 D Photograph (see Fig 2)

A Anterior to the incus

1 There is circumscribed anterior footplate otosclerosis

P Posterior to the incus, from superior to inferior, are

1 The normal Fallopian canal

2 The normal blue translucent footplate deeply placed in the oval window niche

3 The downward tilt of the posterior crus brings it into contact with the inferior lip of the oval window niche This approximation makes the posterior crus susceptible to otosclerotic fixation by the adjacent otosclerotic involvement (Similar to Fig 2 with otosclerosis extending posteriorly adjacent to but not fixing posterior crus)

Comments

At present this patient has a good result which should last unless there is otosclerotic involvement of the posterior crus

Case 6 SR—213 A —Upward Tilt.

Diagnosis

1 Otosclerosis, circumscribed, thin, white, anterior footplate, footplate not seen

2 Stapes fixed very deep, uptilt of crura, contacting Fallopian canal

3 Normal round window

This is an operable but anatomically unfavorable stapes

Description of 3 D Photograph

P Posterior to the incus, from left to right are

1 The normal Fallopian canal

2 *The footplate of the stapes is not visible but in a narrow deep niche*

3 There is marked upward tilt of the crura so that the neck of the stapes is in contact with the Fallopian canal (similar to Fig 3 with no otosclerosis on Fallopian canal)

4 The round window is normal

Comments

This stapes mobilized easily with pressure on the incus The deep footplate with upward tilt of the crura makes the prognosis guarded in this now successful mobilization (see next case) Although anatomically unfavorable, the result has lasted because there was no crural involvement

Case 7 SR—269 L —Upward Tilt Footplate Mobilization and Re-Application of Crura.

Diagnosis

1 Otosclerosis diffuse bi-crural and cervical, with fixation to Fallopian canal and obliteration of 1/2 of footplate

2 Stapes fixed, very deep inaccessible footplate upward tilt.
3 Round window patent but marginal otosclerosis
This is an extensive unfavorable otosclerosis

Description of 3 D Photograph
A Anterior to the incus there is
1 Red otosclerotic involvement of the promontory
P Posterior to the incus from superior to inferior are
1 Otosclerosis of the Fallopian canal
2 Otosclerotic fixation between the Fallopian canal and the neck of the stapes (Cervical otosclerosis—more than Fig 3)
3 Red vascular otosclerosis of the promontory
4 Normal round window
5 Footplate of the stapes is so deep that it is invisible, the resultant upward tilt of the crura predisposed toward the otosclerotic fixation of the neck.

Comments

The red vascular otosclerotic fixation between the Fallopian canal and the neck of this deeply placed stapes, with upward tilt and fixation of both crura, makes this an inoperable stapes by currently accepted mobilization techniques As this 54-year-old male presented 85 db loss and was not suitable for fenestration surgery, the footplate of the stapes was investigated The crura of the stapes were fractured and retracted downward to expose the footplate (The anterior footplate, anterior crural, inferior marginal and posterior crural otosclerosis were more extensive than Fig 5c) Approximately one-half of the footplate was normal blue This central portion of the footplate was mobilized with the chisel The remnant of the stapes still attached to the incus was swung back into position over the mobile central portion of the footplate This operation was done on September 10, 1957 On February 7, 1958 (5 months post-operative), the patient still poossessed a 42 db hearing improvement to the 43 db hearing level

Such bi-crural otosclerosis is beyond the limits of accepted methods of mobilization surgery, and as previously stated, required some type of oval window surgery with or without the application of prosthetic crura

Shea advocates excavation of the oval window and the application of a vein graft and prosthetic crura or re-application of a uni-pod stapes

This is an operable but unfavorable stapes with a deep footplate and downward tilt of the crura

Description of 3 D Photograph (see Fig 2)

A Anterior to the incus

1 There is circumscribed anterior footplate otosclerosis

P Posterior to the incus, from superior to inferior, are

1 The normal Fallopian canal
2 The normal blue translucent footplate deeply placed in the oval window niche
3 The downward tilt of the posterior crus brings it into contact with the inferior lip of the oval window niche This approximation makes the posterior crus susceptible to otosclerotic fixation by the adjacent otosclerotic involvement (Similar to Fig 2 with otosclerosis extending posteriorly adjacent to but not fixing posterior crus)

Comments

At present this patient has a good result which should last unless there is otosclerotic involvement of the posterior crus

Case 6 SR—213 A —Upward Tilt

Diagnosis

1 Otosclerosis, circumscribed, thin, white, anterior footplate, foot plate not seen
2 Stapes fixed, very deep, uptilt of crura, contacting Fallopian canal
3 Normal round window

This is an operable but anatomically unfavorable stapes

Description of 3 D Photograph

P Posterior to the incus, from left to right are

1 The normal Fallopian canal
2 The footplate of the stapes is not visible but in a narrow deep niche
3 There is marked upward tilt of the crura so that the neck of the stapes is in contact with the Fallopian canal (similar to Fig 3 with no otosclerosis on Fallopian canal)
4 The round window is normal

Comments

This stapes mobilized easily with pressure on the incus The deep footplate with upward tilt of the crura makes the prognosis guarded in this now successful mobilization (see next case) Although anatomically unfavorable, the result has lasted because there was no crural involvement

Case 7 SR—269 L —Upward Tilt Footplate Mobilization and Re-Application of Crura.

Diagnosis

1 Otosclerosis diffuse, bi crural and cervical with fixation to Fallopian canal and obliteration of 1/2 of footplate

Comments

In thick, white anterior footplate and anterior crural otosclerosis, the prognosis is favorable, with Fowler's anterior-crurotomy and complete posterior footplate mobilization of the stapes

Case 10 SR—283 SS—Superior Bi-Crural Otosclerosis

Diagnosis

1 Otosclerosis, circumscribed red, thick, superior marginal bi-crural, inferior 1/2 of footplate blue
2 Stapes fixed footplate deep crura upright.
3 Round window normal

Description of 3 D Photograph

P Posterior to the incus, from superior to inferior are

1 The normal Fallopian canal
2 Red vascular otosclerosis along the entire superior margin of the footplate replacing the annulus, fixing the length of the footplate and fixing the superior edge of the anterior and posterior crus and filling the superior 1/2 of the oval window niche (Fig 5d)
3 The inferior half of the footplate is normal translucent blue
4 The inferior margin of the annulus is normal
5 The round window is normal

Comments

It is easy enough to mobilize such a stapes, but there is usually prompt re-fixation with thick, red superior marginal, bi-crural otosclerosis Audiometrically, this bi-crural otosclerosis shows a sloping air-conduction curve with loss of high tones

Because of the marked narrowing of this deep oval window niche, and the fact that this 22-year-old female is suitable for fenestration surgery, I have advised against further oval window surgery, and have encouraged the patient to have a fenestration operation

Case 11 SL—225-MH—Inferior Bi Crural Otosclerosis

Diagnosis

1 Otosclerosis circumscribed white anterior footplate inferior marginal bi-crural 3/4 of footplate blue unfavorable
2 Stapes fixed deep footplate downward tilt of crura
3 Round window normal

Description of 3 D Photograph

A. Anterior to the incus there is

1 A wide area of white anterior footplate and anterior crural otosclerosis

As in this case, at the present time, I feel that such oval window surgery should be reserved for those cases which are no longer suitable for the fenestration operation

Case 8 SR—308—Fallopian Canal Otosclerosis

Diagnosis

1 Otosclerosis circumscribed, red, Fallopian canal to anterior crus, footplate normal
2 Stapes fixed, upright, deep
3 Round window normal

Description of 3 D Photograph

P Posterior to the incus from left to right are

1 The Fallopian canal
2 On the inferior border of the Fallopian canal there is a red prominence of otosclerotic bone projecting downward to fix the superior surface of mid portion of the anterior crus (Similar to Fig 3 but not localized to anterior crus)
3 Deep to the bony prominence there is a normal blue, deeply placed footplate
4 The posterior crus and stapedius tendon are not involved
5 The chorda tympani nerve and round window are normal

Comments

The superior otosclerotic fixation external to a normal footplate is rare Because of the anterior crural fixation an anterior crurotomy was attempted, however, in the process the stapes was completely mobilized, making crurotomy impracticable At present, the hearing is good

CRURAL OTOSCLEROSIS

Case 9 SR—272—Anterior Crural Otosclerosis

Diagnosis

1 Otosclerosis, circumscribed, thick pink anterior crural, footplate 3/4 blue favorable
2 Stapes fixed, moderate superficial upright, strong crura.
3 Round window normal

Description of 3 D Photograph (Less than Fig 4a)

A Anterior to the incus

1 Thick white otosclerosis surrounds the anterior footplate and anterior crus

P Posterior to the incus from superior to inferior are

1 The normal Fallopian canal
2 A moderately deep uninvolved area of the footplate of the stapes
3 A strong free, upright posterior crus
4 A normal round window

3 Upright crura which do not touch the margins of the oval window (similar to Fig 3 without contact)
4 Pink otosclerosis extending over the promontory (similar but less than 6d)
5 Patent round window with marginal round window otosclerosis

Comments

In general re-fixation is prompt in such pink otosclerosis however, this case has maintained hearing improvement This lasting improvement probably occurred because the crura of the stapes were upright, and were not involved in the otosclerotic process In stapes surgery it is the possible combinations of favorable and unfavorable anatomy and pathology which determine operability (see Chart V)

Case 13 SL—247 A —Complete Thin Footplate Otosclerosis

Diagnosis

1. Otosclerosis circumscribed thin white, complete footplate annulus discernable
2. Stapes fixed superficial crura upright, free
3. Round window normal.

Description of 3 D Photograph

P Posterior to the incus from left to right, are

1. The normal Fallopian canal
2. The footplate is superficial and completely replaced by the otosclerotic process The margins of the footplate are thin so that the annular margin of the footplate is visible superiorly and inferiorly (see Fig 6a)
3. The crura are strong upright and do not contact the margins of the oval window
4. The round window is normal

Comments

This appeared to be an inoperable footplate, however, with manipulation at the annulus with the chisel, complete footplate mobilization was obtained, and the patient has a lasting hearing improvement

Six months post-operatively, this patient states that her hearing has remained good, and the audiogram shows a 30 db hearing improvement to the 25 db level

Case 14 SL-237-S —Thick Complete Footplate Otosclerosis

Diagnosis

1. Otosclerosis diffuse red thick, complete footplate with filling of the oval window niche
2. Stapes fixed deep footplate crura free

P Posterior to the incus, from superior to inferior, are
1 The normal Fallopian canal
2 An area of normal blue footplate deeply placed in a narrow niche
3 The normal superior and inferior margins of the footplate
4 The downward tilt of the crura brings the crura into contact with the inferior lip of the oval window there is white otosclerotic fixation of the inferior border of the posterior crus (see Fig 5c)
5 The round window is normal

Comments

This bi-crural fixation of the deeply placed stapes with downward tilt of the crura is, to me, beyond the limits of our present day mobilization surgery In this case, and others, re-fixation has been prompt This is the type of case which might respond to mobilization of the footplate combined with an anterior and posterior crurotomy, and either the insertion of some type of non-osteogenic prosthetic crura, or a Type IV tympanoplasty As the case is clinically suitable, I have advised a fenestration operation

CHARACTER OF OTOSCLEROSIS—COLOR AND THICKNESS

The color of the otosclerosis is dependent upon the vascularity and the activity of the otosclerotic process, the circumscribed white, inactive otosclerosis is difficult to mobilize, but does not tend to re-fix, while the red vascular otosclerosis is easy to mobilize but tends toward prompt re-fixation

White, nearly white, and red otosclerosis has been illustrated by previous cases

Case 12 SL—263 H —Diffuse Pink Otosclerosis

Diagnosis
1 Otosclerosis, diffuse, pink anterior footplate unfavorable
2 Stapes fixed deep, upright, crura not fixed
3 Round window, patent, marginal otosclerosis

Description of 3 D Photograph
A Anterior to the incus
1 There is pink otosclerosis fixing the anterior footplate and extending over the promontory
P Posterior to the incus from superior to inferior, are
1 Pink otosclerosis involving the Fallopian canal
2 A deeply placed almost invisible footplate

3 Upright crura which do not touch the margins of the oval window (similar to Fig 3 without contact)
4 Pink otosclerosis extending over the promontory (similar but less than 6d)
5 Patent round window with marginal round window otosclerosis

Comments

In general re-fixation is prompt in such pink otosclerosis however, this case has maintained hearing improvement This lasting improvement probably occurred because the crura of the stapes were upright, and were not involved in the otosclerotic process In stapes surgery it is the possible combinations of favorable and unfavorable anatomy and pathology which determine operability (see Chart V)

Case 13 SL—247 A —Complete Thin Footplate Otosclerosis

Diagnosis

1 Otosclerosis circumscribed thin white complete footplate annulus discernable
2 Stapes fixed superficial crura upright, free
3 Round window normal

Description of 3 D Photograph

P Posterior to the incus from left to right are

1 The normal Fallopian canal
2 The footplate is superficial and completely replaced by the otosclerotic process The margins of the footplate are thin so that the annular margin of the footplate is visible superiorly and inferiorly (see Fig 6a)
3 The crura are strong upright and do not contact the margins of the oval window
4 The round window is normal

Comments

This appeared to be an inoperable footplate, however, with manipulation at the annulus with the chisel, complete footplate mobilization was obtained, and the patient has a lasting hearing improvement

Six months post-operatively, this patient states that her hearing has remained good, and the audiogram shows a 30 db hearing improvement to the 25 db level

Case 14 SL-237 S —Thick Complete Footplate Otosclerosis

Diagnosis

1 Otosclerosis, diffuse red thick, complete footplate with filling of the oval window niche
2 Stapes fixed deep footplate crura free

- P Posterior to the incus, from superior to inferior, are
  1. The normal Fallopian canal
  2. An area of normal blue footplate deeply placed in a narrow niche
  3. The normal superior and inferior margins of the footplate.
  4. The downward tilt of the crura brings the crura into contact with the inferior lip of the oval window there is white otosclerotic fixation of the inferior border of the posterior crus (see Fig 5c)
  5. The round window is normal

Comments

This bi-crural fixation of the deeply placed stapes with downward tilt of the crura is, to me, beyond the limits of our present day mobilization surgery In this case, and others, re-fixation has been prompt This is the type of case which might respond to mobilization of the footplate combined with an anterior and posterior crurotomy, and either the insertion of some type of non-osteogenic prosthetic crura, or a Type IV tympanoplasty As the case is clinically suitable, I have advised a fenestration operation

CHARACTER OF OTOSCLEROSIS—COLOR AND THICKNESS

The color of the otosclerosis is dependent upon the vascularity and the activity of the otosclerotic process, the circumscribed white, inactive otosclerosis is difficult to mobilize, but does not tend to re-fix, while the red vascular otosclerosis is easy to mobilize but tends toward prompt re-fixation

White, nearly white, and red otosclerosis has been illustrated by previous cases

Case 12 SL—263 H —Diffuse Pink Otosclerosis

Diagnosis
1. Otosclerosis diffuse pink anterior footplate, unfavorable
2. Stapes fixed deep upright crura not fixed
3. Round window, patent, marginal otosclerosis

Description of 3 D Photograph
- A Anterior to the incus
  1. There is pink otosclerosis fixing the anterior footplate and extending over the promontory
- P Posterior to the incus, from superior to inferior, are
  1. Pink otosclerosis involving the Fallopian canal
  2. A deeply placed almost invisible footplate

dow closure Had the oval window not been completely closed, I would have proceeded with the fenestration operation

POST-MOBILIZATION PATHOLOGY

Re-fixation of the stapes, or primary mobilization failures, may result from either technical or pathological causes Re-fixation of the stapes may result from inadequate surgery, but more frequently re-fixation occurs in unfavorable or inoperable anatomical and pathological circumstances This is the cause for re-fixation after complete mobilization Inadequate surgery includes incomplete mobilization, and failure to do an anterior-crurotomy in anterior crural otosclerosis

Primary mobilization failures may result from inexpert surgery, or improper surgical attack, more frequently, primary failures occur to the reasonably competent surgeon, because the pathology present was beyond the limits of stapes mobilization surgery A primary mobilization failure of inexpert surgery may convert a thoroughly operable stapes into an unfavorable or inoperable stapes

Re-operation on the stapes is rarely indicated because of probable primary unfavorable pathology and secondary scar formation Re-operation on the stapes is indicated only when the primary pathology and anatomy were found to be favorable Re-operation on the stapes should never be performed as a "solo" operation, for too often the re-operated stapes is found to be inoperable, therefore, in re-operation of the stapes one should be prepared to do a "fenestration in continuity" should the stapes prove to be pathologically inoperable

Case 16 SR—65-FR—713 EF

Diagnosis

1. Post mobilization fibrosis severe
2. Otosclerosis circumscribed anterior footplate anterior crural.
3. Stapes fixed deep footplate downward tilt
4. Round window normal.

Description of 3-D Photograph

This is a post-operative mobilization primary failure in which we are performing a fenestration operation and have exposed the entire incus

3 Round window normal

Description of 3 D Photograph

P Posterior to the incus, from superior to inferior, are

1 A normal Fallopian canal

2 A deeply placed footplate completely covered with thick, red, vascular otosclerosis which fills the oval window niche to apex of the crura of the stapes (see Fig 6b)

3 The round window is normal

Comments

Thick, red, complete footplate otosclerosis is inoperable and is a pathological indication for the fenestration operation I do not believe that oval window surgery will ever be applicable when the otosclerosis is so thick that the margins of the footplate are obliterated, and there is no remaining normal footplate

When exploration revealed the above described pathology, the operation was discontinued and a fenestration advised It is not necessary to fracture the crura, or to drive a chisel into the footplate, to know that mobilization would be a failure

Case 15 FL-718 B —Inoperable Otosclerosis, Oval and Round Window

Diagnosis

1 Otosclerosis, diffuse, red, anterior footplate inferior marginal, bi-crural, promontory, oval window

2 Stapes fixed, deep footplate, downward tilt

3 Round window, complete closure

Description of 3 D Photograph

P Posterior to the incus from superior to inferior, are

1 The normal Fallopian canal

2 A very deep, almost occluded footplate of the stapes

3 Downward tilt of the crura of the stapes, with complete otosclerotic fixation of one-half of the posterior crus (worse than Fig 6d with complete round window closure)

4 Red, vascular, otosclerosis of the promontory

5 Complete slit like closure of the round window

Comments

A primary fenestration was advised because of the positive Schwartze sign, but surgery was discontinued when exploration revealed the complete round window closure A fenestration may be of value if even a fraction of the round window is patent A hearing aid is indicated in complete round winstapes surgery in the first ear, I advise a fenestration on this ear before exploring the stapes on the opposite ear If the pathology was favorable in the first ear and the mobilization was a failure for technical reasons, a mobilization is performed on the opposite ear

Case 18 SL—276-FL—721-MD—Unfavorable Stapes

Diagnosis

1 P O stapes primary failure

2 Otosclerosis circumscribed anterior footplate anterior crural, inferior marginal posterior footplate, footplate 1/5 blue

3 Stapes, footplate deep, crura downward tilt fractured bound with adhesion

4 Round window normal

Description of 3 D Photograph

1 The incus scar tissue and crura of the stapes have been removed, exposing the oval window niche and footplate, from superior to inferior are

1 The ampulla of the horizontal canal

2 The Fallopian canal

3 The deeply placed footplate of the stapes showing anterior and posterior footplate otosclerosis involving the stumps of the crura. The circumscribed white otosclerosis extends onto the promontory for about 1 mm (more than Fig 5c)

Comments

The stapes mobilization was a primary failure because of the crural and footplate otosclerosis Because of the small central area of blue footplate (1/5) some might advise excavation of the oval window and the application of prosthetic crura As a secondary operation, in a suitable candidate, I prefer the more reliable and predictable fenestration

Some surgeons justify multiple stapes operations on the patient's temporary objections to a fenestration Unless the secondary surgical procedure is reasonably predictable, I advise a hearing aid

Case 19 SL—99 FL—720-EK.—Inoperable Footplate

Diagnosis

1 P O stapes primary failure

2 Otosclerosis diffuse thick pink, complete footplate annulus obliterated crura atrophic

3 Stapes fixed superficial crura upright weak no fibrosis

4 Round window normal

Descroption of 3 D Photograph

1 A fenestration is being performed the incus has been removed from superior and inferior are

P Posterior to the incus, from superior to inferior, are
  1 The Fallopian canal covered with scar tissue
  2 Firm fibrous adhesions occlude the view of the deep footplate of the stapes and bind the stapes and stapedius tendon to the Fallopian canal and incus to the chorda tympani nerve tympani membrane and promontory

Comments

These fibrous adhesions of a deeply placed stapes, with downward tilt of the crura, make this an inoperable stapes and is a pathological indication for the fenestration operation

Case 17 S—67 F—715 A—Probable Technical Failure

Diagnosis
  1 P O mobilization, re-fixation
  2 Otosclerosis anterior footplate anterior crural, inferior marginal firm fibrous adhesions
  3 Stapes fixed, deep, downward tilt.

Description of 3 D Photograph

P The incus has been dislocated from superior to inferior are
  1 The ampulla of the horizontal canal
  2 The Fallopian canal
  3 The deeply placed footplate
  4 Downward tilt of the posterior and inferior crus of the stapes otosclerosis fixing 1/2 of the anterior crus (see Fig 5a)
  5 Fibrous adhesions fixing the stapes

Comments

This re-fixation of the stapes is probably a technical failure, for the patient has a good mobilization on the opposite ear, and in bilateral otosclerosis the pathology in the two ears is similar Anterior crurotomy may have prevented re-fixation In the opposite ear, the patient has maintained a 30 db hearing improvement to the 15 db level for 18 months In the operated ear under discussion the patient obtained a 25 db gain to the 30 db level with prompt loss of the gain As the secondary anatomy and pathology were unfavorable, a fenestration was performed yielding a 35 db gain to the 20 db level

In cases that have had stapes mobilization on both ears, if they have obtained one good result they are anxious to have a fenestration on the opposite ear, however, if both mobilizations have been a failure, they are reluctant to try any further surgery If the pathology is found to be unfavorable for

A fenestration is performed in continuity when the pathology is found to be beyond the limits of mobilization surgery The decision to perform a fenestration in continuity is based, not upon the blind audiometric failure, but upon the microscopic fact that the footplate is not mobile, and that the pathology is beyond the limits of stapes surgery

Case 21 FR—717 BS—Unfavorable Stapes

Diagnosis

1 Otosclerosis white circumscribed anterior footplate anterior crural inferior marginal posterior crural unfavorable
2 Stapes fixed deep downward tilt.
3 Round window normal.

Description of 3 D Photograph

A. The incus has been disarticulated, from superior to inferior are

1 The ampulla of the horizontal canal
2 The normal Fallopian canal
3 The deeply placed footplate of the stapes
4 There is a downward tilt of both crura white otosclerosis is seen to involve one-third of the anterior crus extend along the entire inferior margin of the footplate and involve the posterior crus (see Fig 5c)

Comments

When exploratory tympanotomy revealed this unfavorable pathology we proceeded with a "fenestration in continuity" without attempting mobilization The patient and the operating staff had been previously prepared, because of the sloping air-conduction audiogram with the disproportionate loss of high tones It would have been easy enough to mobilize this stapes, but in my present clinical opinion, the result would have been temporary, because of the bi-crural otosclerosis

Some surgeons advise that a stapes mobilization should always be tried first. A thesis of this study is that this trial and failure approach should be replaced by sound surgical judgment, based upon the clinical interpretation of the existing pathological circumstances

CLINICAL COMMENTS

1 Stapes mobilization is the operation of choice in early and moderate circumscribed otosclerosis

1 The ampulla of the horizontal canal
2 The Fallopian canal
3 The footplate of the stapes is completely replaced by thick, pink, otosclerosis with obliteration of the annulus, there is no scar formation
4 The crura are atrophic
5 The round window is normal.

Comments

At the primary mobilization the crura of this inoperable stapes were fractured This thick footplate is beyond the operable limits of any known type of oval window surgery The fenestration was performed with a 26 db gain to the 22 db level

FENESTRATION IN CONTINUITY

Case 20 FR—710 H—Inoperable Stapes

Diagnosis

1 Otosclerosis, circumscribed, complete footplate, white, flat, 1+ thick, annulus upright, strong
2 Stapes fixed, superficial footplate, crura upright, strong
3 Normal round window

Description of 3 D Photograph

P Posterior to the incus from superior to inferior are
1 The normal Fallopian canal
2 The footplate is broad, white, superficial, with the annulus almost obliterated (between Fig 6a and b)
3 The posterior crus is strong and upright
4 The round window is normal

Comments

Because of the severity of the deafness (80 db), a fenestration was advised, anticipating an inoperable stapes When the exploratory tympanotomy revealed the anatomically favorable strong upright crura, and the anatomically favorable superficial footplate with white otosclerosis, efforts were made to mobilize the footplate, even though there was complete footplate otosclerosis with beginning obliterations at the annulus The chisel was used completely around the annulus of the footplate, but the footplate could not be mobilized A fenestration was performed in continuity, with resultant 37 db gain

In other instances, I have prepared for a fenestration and done a mobilization when the stapes proved to be operable

11 Complete otosclerosis of the footplate may still present a flat audiogram if there is no crural fixation, at least until the otosclerosis becomes too thick or the crura too weak to transmit sound

12 Bi-crural otosclerosis with round window closure is indicated clinically by the very severe associated "nerve" loss

RE-FIXATION AND SECONDARY SURGERY

13 Re-fixation of the stapes may result from inadequate surgery

14 Most instances of re-fixation of the completely mobilized stapes result from unfavorable surgical anatomy and surgical pathology

15 Re-operation on the stapes is indicated only in the presence of the most favorable anatomy and pathology, and primary incomplete mobilization

16 Re-operation on the stapes is contra-indicated in unfavorable anatomy and pathology, unfavorability includes both the primary otosclerosis and the secondary post-mobilization cicatrization

17 At the present time, in clinically suitable cases, I favor the fenestration operation over anterior and posterior crurotomy, and mobilization of the footplate alone or excavation of the footplate and the application of prosthetic crura

18 Many stapedial footplates are so involved that they cannot be mobilized or excavated, and are an unequivocal indication for the fenestration operation in clinically suitable cases

19 Adequate exposure and adequate magnification are advocated to

1 Give maximum opportunity for varied surgical attack on the variable anatomy and pathology of the stapes

2 To determine the pathological limitations of the stapes surgery

3 To determine the pathological indication for fenestration surgery

2 In bilateral otosclerosis the anatomy and pathology of the stapes are similar in type, though they may vary in degree

3 If the stapes mobilization on the first ear reveals favorable surgical pathology and favorable surgical anatomy, a mobilization is advised on the opposite ear

4 If the stapes mobilization has been primarily successful in the presence of unfavorable pathology, the patient is advised of these findings and that he will probably need a fenestration While the hearing is still good and the morale high, he is given a tentative date for the subsequent fenestration (interval about three months)

5 (a) If the first stapes mobilization was a failure, the surgical pathology is unknown, and the operated ear is the poorer ear, a fenestration operation is advised on this ear (see secondary mobilization surgery)

(b) If at the time of the fenestration, examination reveals that the stapes was primarily operable, subsequently a stapes mobilization is performed on the opposite ear

6 If the first stapes mobilization is a failure, the surgical pathology unknown, and the unoperated ear is the poorer ear, an exploratory tympanotomy is done on the unoperated ear and a mobilization or fenestration done, depending upon the pathological findings

7 A positive Schwartze sign is probably a contra-indication to mobilization surgery, certainly it is a contra-indication to a "solo" mobilization

8 In mobilization surgery crural otosclerosis is an indication for crurotomy to prevent re-fixation

9 Bi-crural otosclerosis is probably a contra-indication to mobilization surgery, although in the severely deaf some improvement may result from anterior and posterior crurotomy and mobilization or excavation of an operable footplate, with or without the application of prosthetic crura

10 Bi-crural otosclerosis is believed to be indicated clinically by otosclerotic loss of the high tones

SUMMARY

1 There are specific pathological indications for stapes surgery and there are specific pathological indications for fenestration surgery

2 The operability of the stapes is based upon the type of anatomical development, the degrees of pathological involvement and the possible combinations of these variables

3 There is often a direct correlation between the severity of the deafness, the pathological involvement and the operability of the stapes

4 A basic classification of the anatomy and pathology is presented, degrees of involvement are presented for coding of anatomy and pathology and the classification of surgical results

5 Any classification of results of stapes surgery should be based upon the type of anatomical development, and the type of pathological involvement In this way we will ultimately define the operability of the stapes

6 Current opinions are expressed relative to the favorable, unfavorable, and inoperable stapes, based upon the anatomical development and pathological involvement

7 The variable operability of the stapes is described in a series of illustrative cases

8 The stapes mobilization operation is a reliable surgical procedure in favorable anatomical and pathological circumstances

9 Stapes surgery has enough advantages to make it worthy of a trial in less favorable anatomical and pathological circumstances

10 The fenestration operation is indicated when the anatomical development and pathological involvement are beyond the limits of reasonably predictable stapes surgery

11. If the stapes surgeon strives to obtain the maximum percentage of primary mobilization results in all types of pathological involvement, he will jeopardize the functions of many inner ears with little gain in the percentage of cases with lasting hearing improvement We are learning the limits of successful mobilization surgery

12 Unfavorable pathology is the most frequent cause for re-fixation after complete stapes mobilization

13 Incomplete stapes mobilization or inexpert surgery may convert an operable stapes into an inoperable stapes

14 Re-operation of the stapes is rarely indicated unless the first surgery revealed favorable pathology and the mobilization was incomplete

15 True, the inoperability of the stapes cannot be determined without microscopic inspection of the pathology, but inoperability may be suspected if there is a positive Schwartze, a high tone loss, or if the patient is very hard of hearing (50 db or more)

16 The inoperable stapes is a firm pathological indication for the fenestration operation in a clinically suitable case Inoperability of the stapes may result from extensive otosclerosis, vascular otosclerosis, post-mobilization cicatrization, adhesive processes, or a combination of these, with unfavorable anatomical development

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SUPRAGLOTTIC SUBTOTAL LARYNGECTOMY AND RADICAL NECK DISSECTION FOR CARCINOMA OF THE EPIGLOTTIS

JOSEPH H OGURA, M D ,*†

St Louis, Mo

The presently accepted method for the surgical treatment of cancer of the epiglottis is total laryngectomy and radical neck dissection,[1-8] yet, in certain instances of carcinoma of the epiglottis, the surgeon must wonder whether sacrifice of the entire larynx and the commission of the patient to permanent tracheostomy is entirely necessary

The objective of the surgeon should be not only adequate removal of the lesion but also preservation of laryngeal physiology Peroral amputation of the epiglottis in the absence of nodal metastases has never received popular acceptance, since obviously a wide margin of safety could not be accomplished Although partial laryngectomy with preservation of cordal function is possible, it requires the creation of a large pharyngostoma The attendant dysphagia, drooling of saliva and multiple subsequent operations to effect closure have influenced surgeons into taking the easier course of total laryngectomy

Supraglottic subtotal laryngectomy and radical neck dissection as a one-stage operation for carcinoma of the epiglottis was developed in an attempt to conserve the function of the larynx. In South America the procedure is known as the partial horizontal laryngectomy[9,10] The procedure described here differs from the South American method in that primary closure is performed, rather than to create a pharyngostoma which necessitates a second operation at a later date

The rationale of the proposed surgical procedure is based

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†Department of Otolaryngology Washington University School of Medicine St Louis Mo

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To be published (When I presented this material at the Academy I learned that Ruedi was conducting a parallel study and that many of his ideas are similar I have been unable to obtain a copy of his paper and this reference is included here for completeness)

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MICHIGAN MAN WINS HEARING SOCIETY AWARD

Stuart L Edmonds, Midland, Mich, was recently named winner of the American Hearing Society's Kenfield Memorial Scholarship, an award made annually to a prospective teacher of lipreading Mr Edmonds is the first man to receive the honor since establishment of the scholarship fund in 1937

Mr Edmonds has a bachelor's degree in speech correction, University of Michigan, and a master's degree in education, Eastern Michigan College of Education, Ypsilanti He has taught speech correction in his home State for five years

He is currently employed as field service consultant for the Michigan Association for Better Hearing, a job which has acquainted him with the urgent need for teachers of lipreading Through funds from the scholarship, he plans to take a course at Northwestern University in Methodologies for Teaching Speech Reading branes and ligaments. The apex of this cone-shaped structure ends just superior to the anterior commissure of the true vocal cord, and is less than one-half the distance between the superior notch and the inferior border of the thyroid cartilage (see Fig. 1).

Studies of larynges removed for primary malignant tumors of the epiglottis may show an invasion of the tumor into the preepiglottic space, and anatomically this space is quite separate from the true vocal cords.[13] In less advanced epiglottic carcinoma, when the lower edge of the tumor is at the region of the petiole, there may be microscopic evidence of further extension of tumor to the false cords. Extension to the anterior commissure of the true cords, ventricle, aryepiglottic fold or arytenoids is a late manifestation. In the latter instance, a bilateral neck dissection with total laryngectomy,

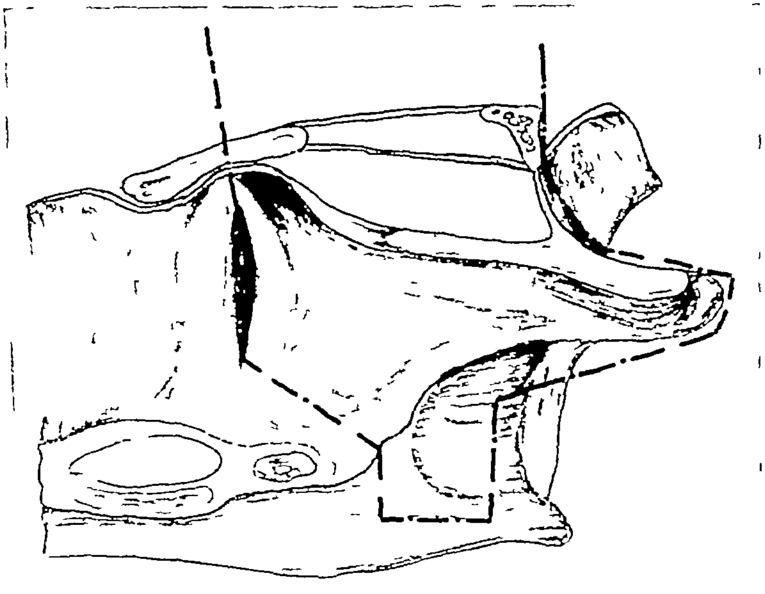

Fig. 2. Surgical Criteria. Lateral view of epiglottis and pre-epiglottic space, vertical section. The dotted line includes the area removed with a radical neck dissection.

on embryological, anatomical, clinical and pathological principles The embryological studies of Most[11] and the work of Rouviere[12] show that the lymphatic pathways from the supraglottic area are independent of those from the true cords and the subglottic areas The supraglottic portion of the larynx develops from the primitive pharynx while the glottis and subglottic area are derived from the superior extremity of the tracheal tube The ventricular bands, epiglottis and the anterior part of the aryepiglottic fold arise from the fourth branchial arch The separate lymphatic collecting pathways from the supraglottic and the cordal with subglottic area would suggest that the two sites could be divided from one another without violating sound principles of cancer surgery

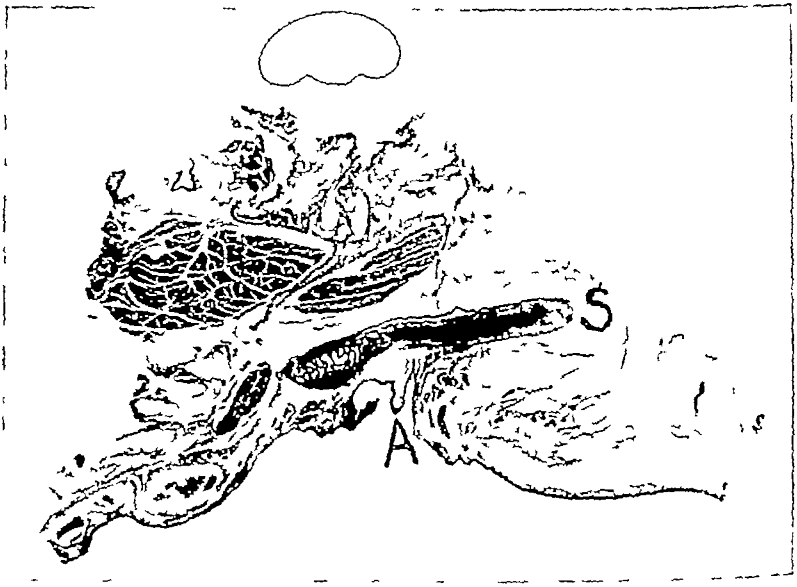

Fig 1 The relation of the anterior commissure to the thyroid cartilage Note the inferior position of the anterior commissure—A From the superior border of the thyroid cartilage S Low power vertical section

The preepiglottic space anatomically is confined between the hyoid and anterior commissure of the true vocal cords, shaped like a pyramid with the base up, and bounded laterally by the hyoepiglottic and hyothyroid and thyroepiglottic mem-

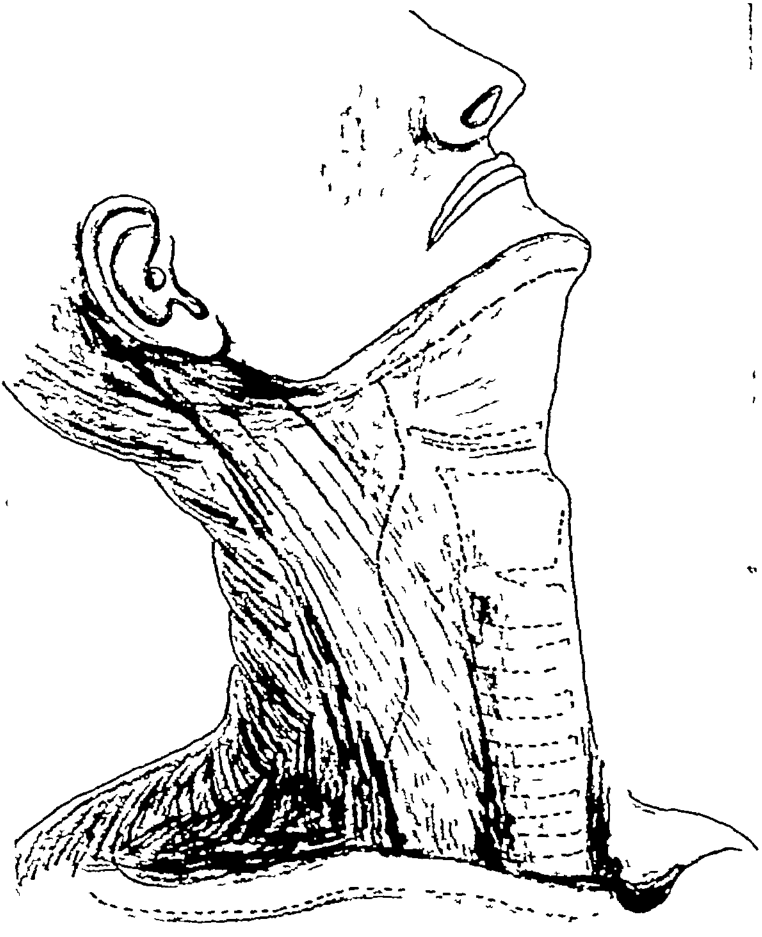

Fig 4 The Incision Note curved incision to minimize secondary contraction

from epiglottic carcinoma, continuity *en bloc* removal of the primary lesion and the cervical nodes must be done as a one-stage procedure if one is to maintain good oncologic principles Such an operation would create a large pharyngeal opening and would necessitate some method for closure In South America a secondary operation has been found necessary[8, 9] It is my purpose to demonstrate that primary closure in my experience, has often been necessary LeRoux-Robert[11] has demonstrated that carcinoma of the epiglottis seldom extends below the cords into the subglottic area, hence, on an embryological, anatomical and pathological basis it should be possible, in selected instances, to remove the entire lesion and preserve the function of the true vocal cords if the resulting pharyngostoma could be closed

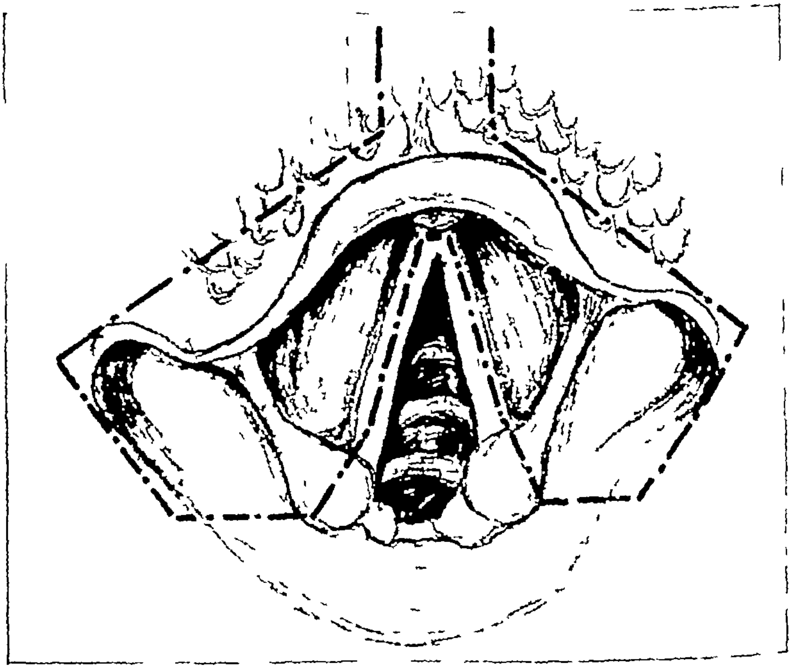

Fig 3 Surgical Criteria Mirror view of larynx dotted line indicates area of excision

Some surgeons have tried to solve the problem of surgical excision by a transhyoid pharyngotomy approach and amputating the epiglottis without horizontal transection of the thyroid cartilage Obviously, the entire preepiglottic space cannot be removed by this method The laryngofissure approach has the disadvantage in that the upper end of the incision will open the preepiglottic space and divide the cords at the anterior commissure

Since metastases to the lateral cervical nodes are frequent

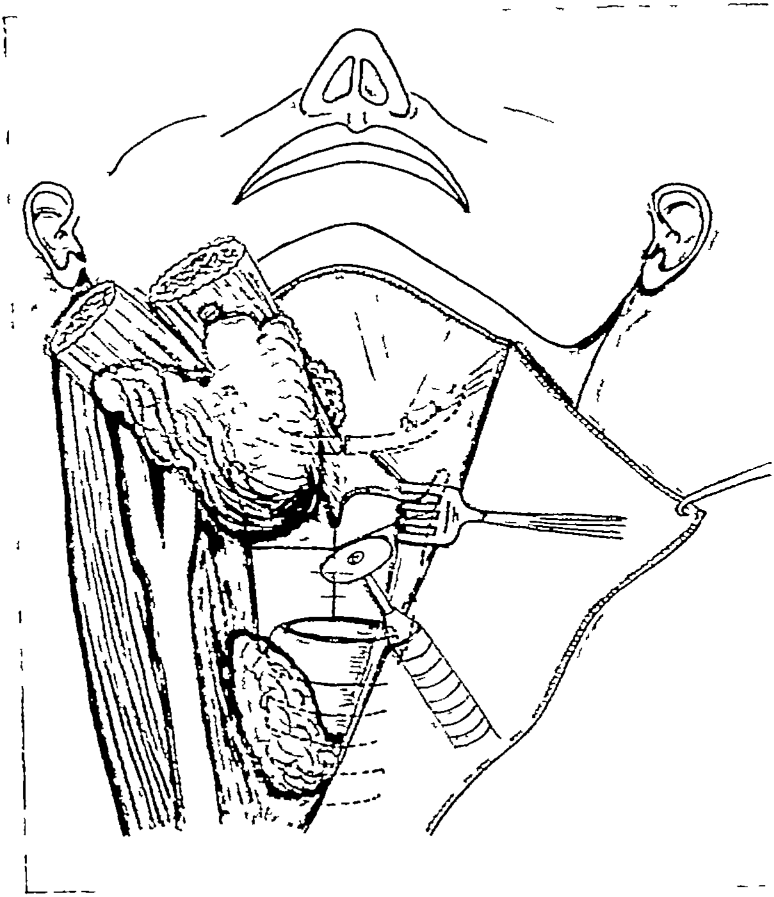

Fig 6 Thyroid cartilage is divided transversely one-third the distance from thyroid notch to the inferior border

2 The lower border of the tumor should not extend below the petiole It is better if there is a greater margin of safety between the lower border of the tumor and the anterior commissure of the true vocal cords

3 Lateral infiltration of the arytenoepiglottic folds and arytenoid edema must be absent

4 The base of the tongue should be clear of tumor—(when

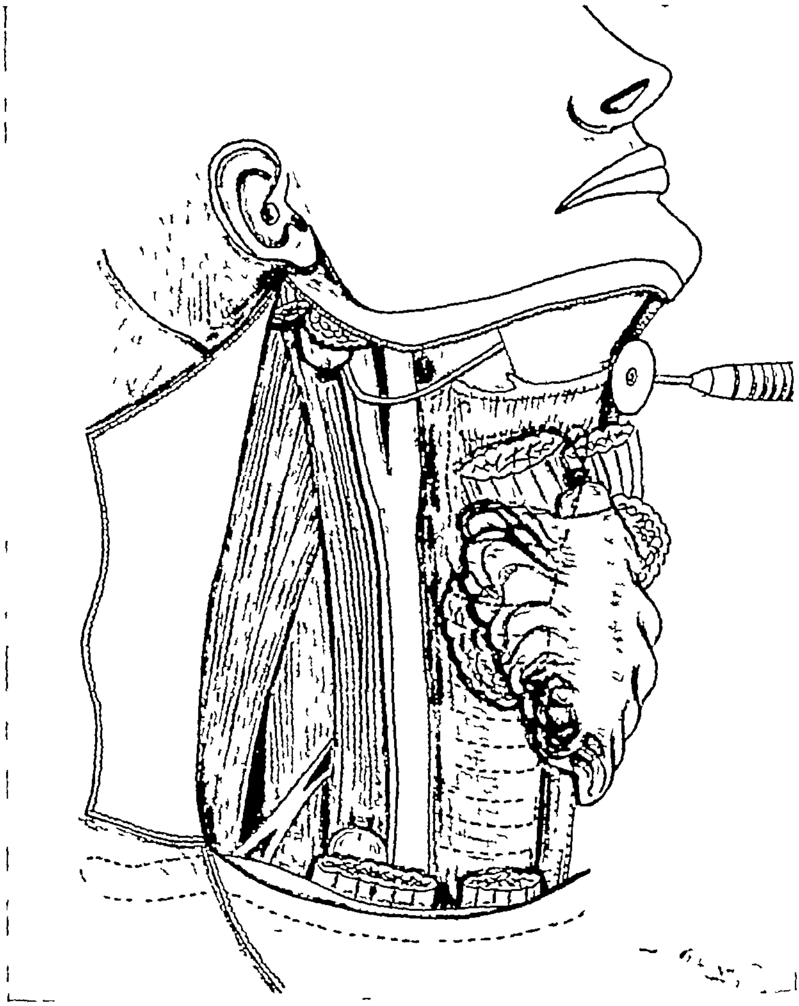

Fig 5 Radical neck dissection completed Note attachment to hyothyroid area sternohyoid and hyothyroid muscles are severed and hyoid bone is divided in midline

of this defect can be accomplished in one operation with restoration of the deglutition and cordal function

SURGICAL CRITERIA

1 The tumor involving the epiglottis should be limited entirely to the cartilaginous laryngeal surface, preferably more towards the free surface (see Figs 2, 3)

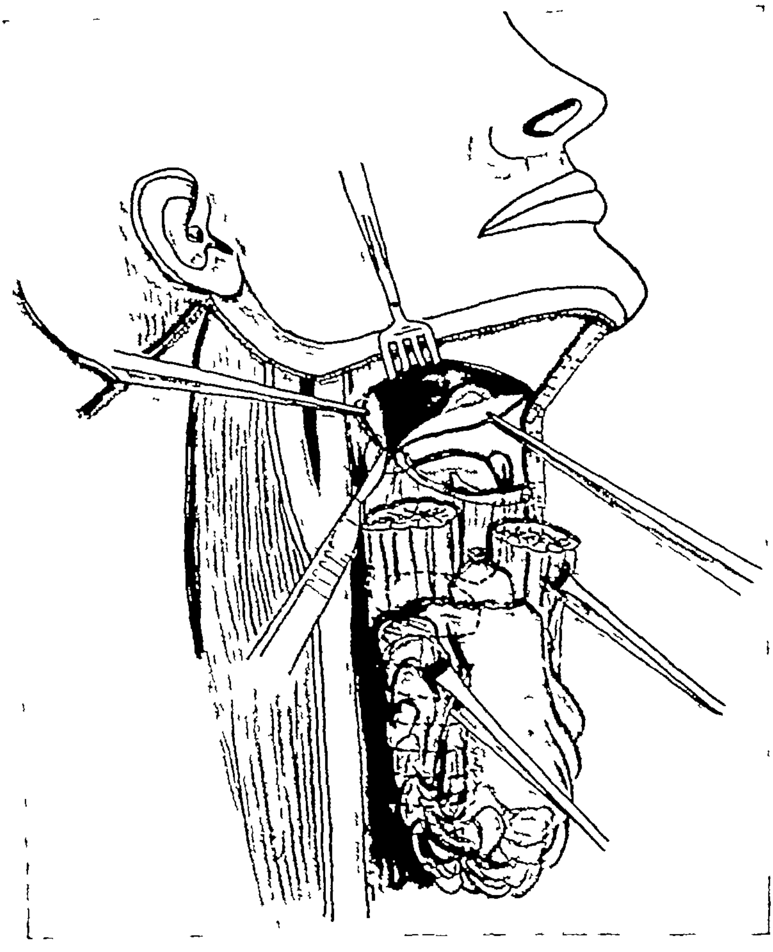

Fig 8 The lateral laryngo-pharyngeal wall is opened inferiorly along the posterior laryngopharynx.

frequently with exophytic lesions, they are more favorable clinically than those that are infiltrative and ulcerative

8 Clinical invasion of the hyothyroid membrane should be absent

9 If nodes are not palpable, a neck dissection is done on the side on which the tumor seems to show the greatest extent

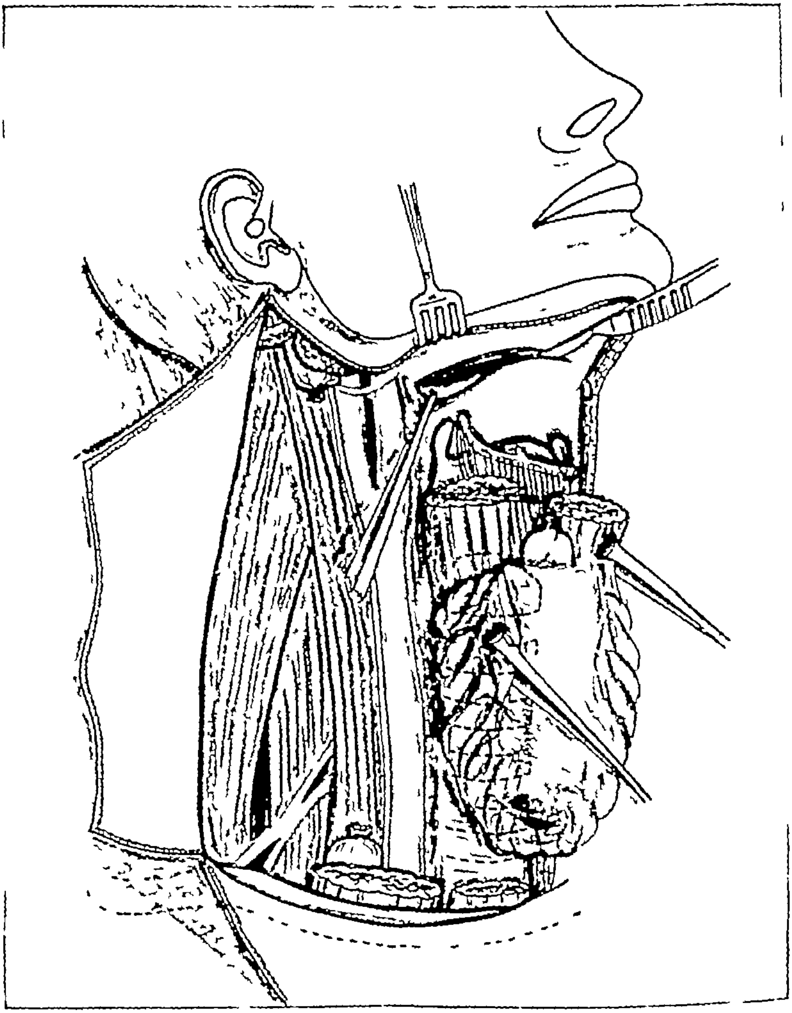

Fig 7 The pharynx is entered in the region of the vallecula and lateral glosso-epiglottic fold

the tip of the epiglottis on the glossal surface shows some tumor, a section of the base of the tongue is removed)

5 The true vocal cords should be free of tumor and show no impairment of motion

6 There should be no gross evidence of false cord invasion

7 Because extension into the preepiglottic space occurs less

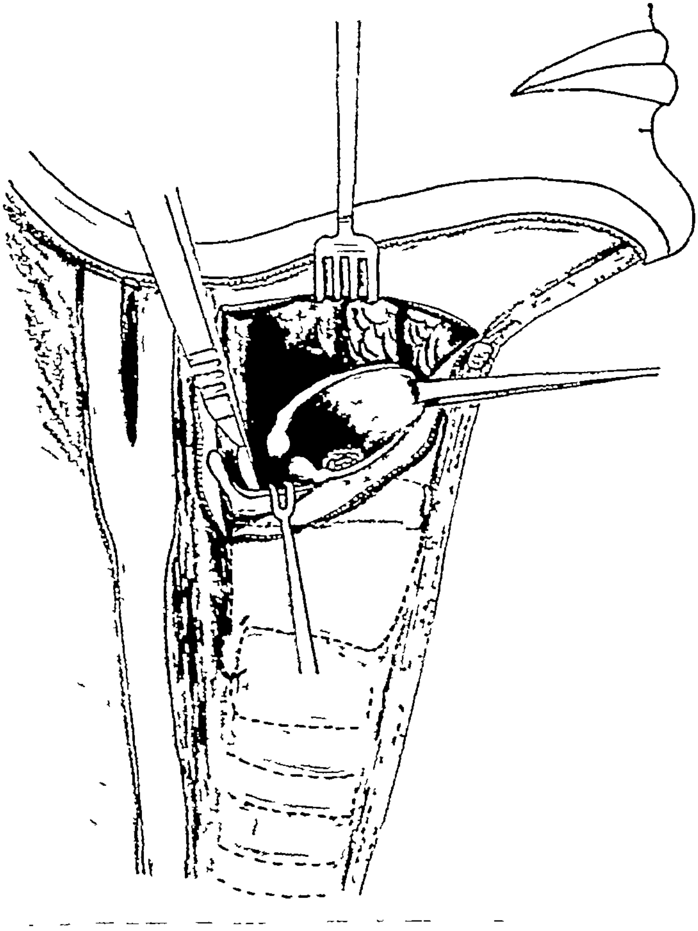

Fig 10 Dissection inferiorly and posterior to the superior cornu of the thyroid cartilage towards the horizontally transected thyroid cartilage

and endotracheal anesthesia is started A neck dissection is carried out in the classical fashion described by many authors over the past five decades[5, 16-20] The classical incision that has been modified and described by Huffman and Lierle has been used in this operation (see Fig 4) The neck dissection in this instance differs from the usual procedure in the following aspects No attempt is made to preserve the spinal accessory nerve whether or not nodes are palpable The

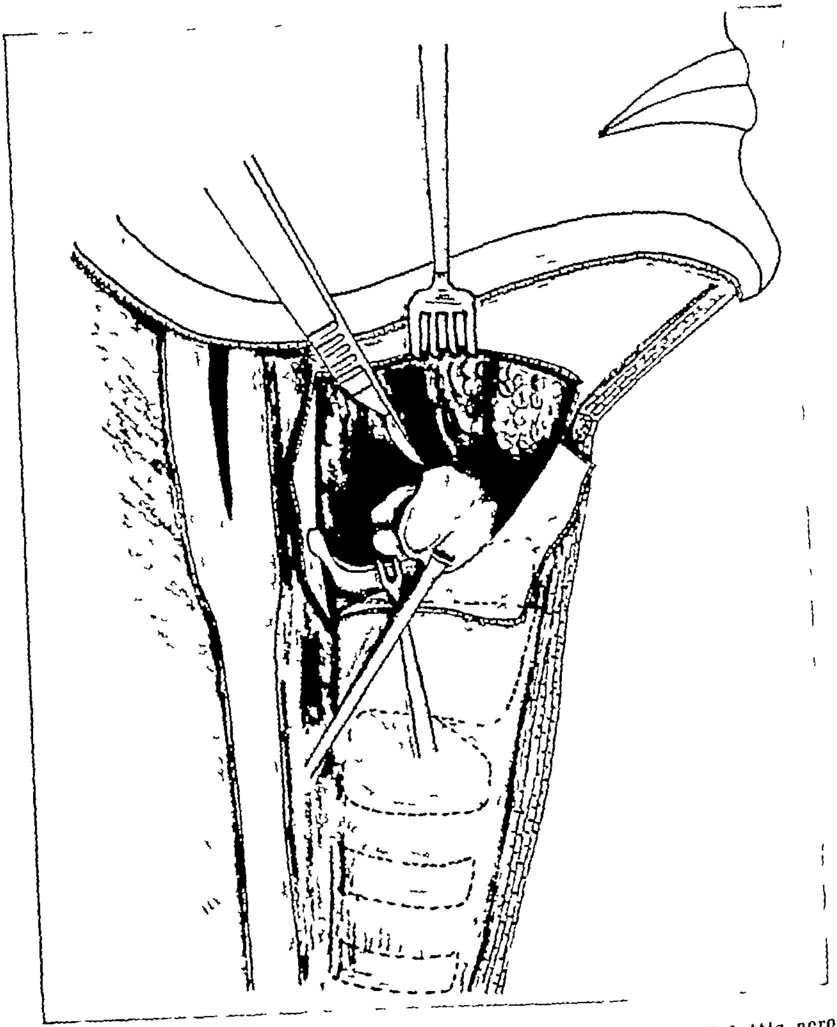

Fig 9 The base of the tongue is separated from the epiglottis across the midline

10 Bilateral palpable nodes warrant a bilateral neck dissection

11 Laryngograms using Dionisil as a contrast media are of great value[15]

TECHNIQUE

A preliminary tracheotomy is done under local anesthesia

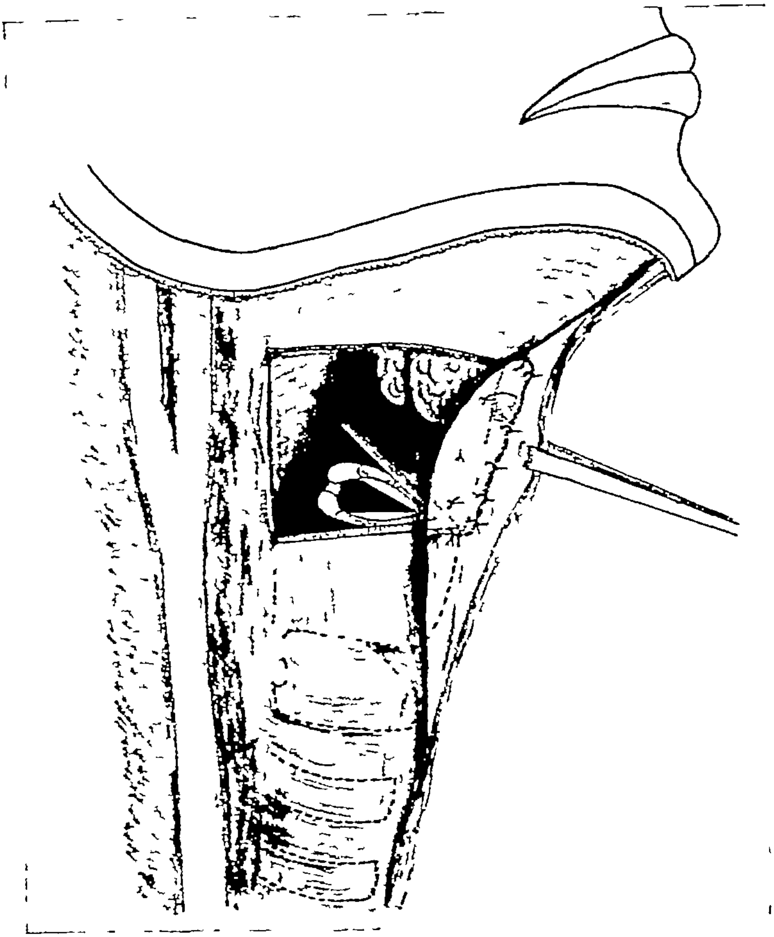

Fig 12 A thick split thickness skin graft is sutured on a muscle rotation flap

The suprahyoid muscles are separated from the hyoid bone on the side of the neck dissection to the midline, and the hyoid bone is divided in the midline and grasped with a tenaculum to be held inferiorly for a landmark (see Fig 5) It is not separated from the specimen

The thyroid cartilage is transectioned with a Stryker saw at a level one-third of the distance between the thyroid notch and the inferior border (see Fig 6)

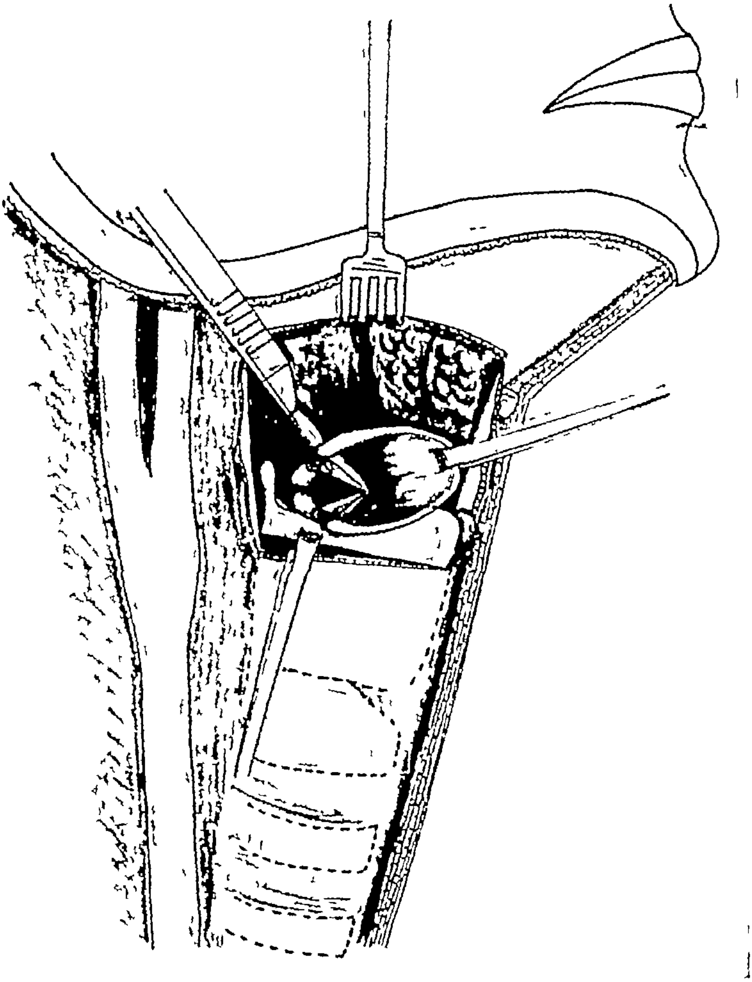

Fig 11 The aryepiglottic folds are sectioned close to the arytenoid and carried anteriorly into the horizontally transected thyroid cartilage, this separates the false cord-ventricle from the true vocal cords

sternothyroid and sternohyoid muscles are transected at the lower level of the thyroid cartilage on the side of the tumor to the midline A complete block neck dissection is performed, but the specimen is left attached to the lateral thyrohyoid area The thyroid lobe on the side of the neck dissection is removed, and great care is given to preserve the recurrent laryngeal nerve cision is carried posteriorly to the superior segment of the horizontally transected thyroid cartilage For further mobilization, the base of the tongue is separated from the epiglottis across the midline (see Figs 8, 9, 10)

The ipsilateral aryepiglottic fold is now sectioned close to the arytenoid cartilage Care should be taken not to expose the arytenoid cartilage The ipsilateral false cord is separated from the true cord, and at the same time further separation is carried anteriorly and laterally into the previously transected portion of the thyroid cartilage Dissection is then carried towards the anterior commissure of the true vocal cords separating it from the ventricle, false cord and epiglottis As dissection is carried across to the opposite side it will include a segment of the opposite transected thyroid cartilage, but less lateral laryngopharyngeal wall is sacrificed The contralateral false cord is divided from the true cord and final separation of the contralateral aryepiglottic fold close to the arytenoid is the last step (see Fig 11) In this manner the entire preepiglottic space together with the epiglottis, false cords, aryepiglottic folds and most of the ventricle (except its inferior surface represented by the superior surface of the true cord) is removed

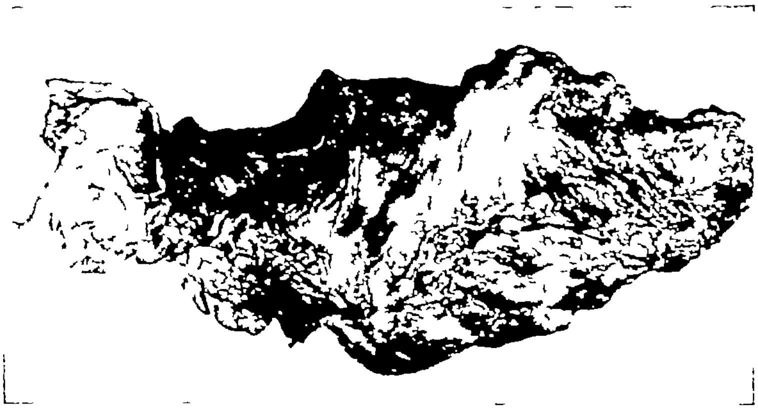

Fig 14-A. Specimen removed

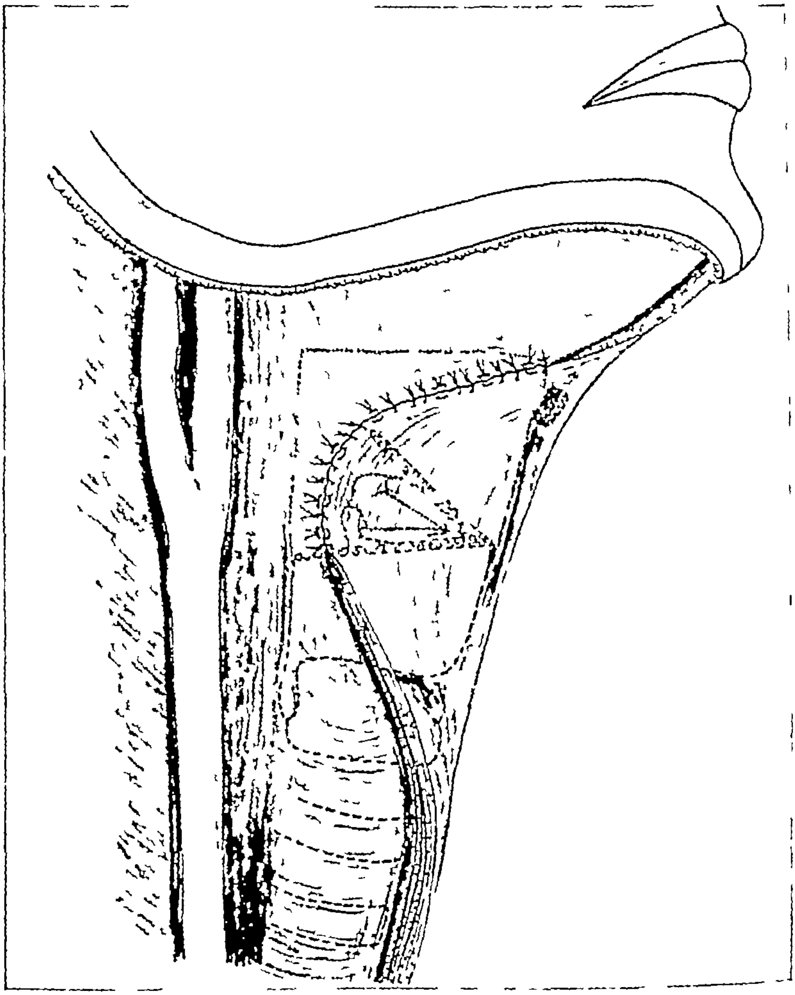

Fig 13 Laryngopharynx approximated with two layers of interrupted silk

On the side of the neck dissection, the sternothyroid and sternohyoid muscles are divided transversely from the midline toward the side of the neck dissection

A pharyngostoma is created by entering the pharynx superior and lateral to the vallecula (in the region where the suprahyoid muscles were separated from the hyoid (see Fig 7) With sharp dissection the entire lateral laryngopharyngeal wall is separated from the posterior wall, and the in-

A Penrose drain is placed into the lateral neck area, and the skin is closed by approximation of the subcutaneous tissues with silk and interrupted silk for the skin A tracheotomy tube is inserted following removal of the endotracheal tube

In the event that a bilateral neck dissection is necessary, then there are no strap muscles to rotate since they are removed with the transected thyroid cartilage In this case the entire tongue is mobilized and the laryngopharynx is obliterated by suturing the base of the tongue to the remaining larynx In the postoperative period, antibiotics and feeding by nasal tube is started

Fig 15-A. Specimen removed bilateral neck dissection

RESTITUTION OF DEGLUTITION

It is obvious that since both superior laryngeal nerves are sectioned by this supraglottic approach, feeding difficulties will develop

After a period of ten days to two weeks, the patient is allowed to take food by mouth The patient must relearn

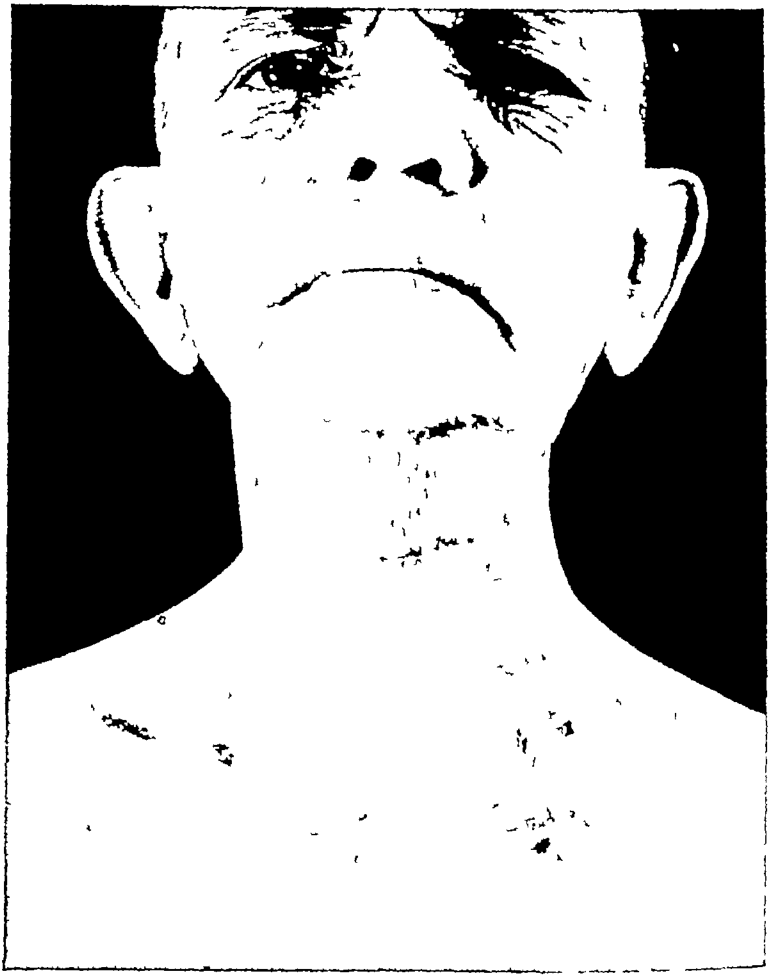

Fig 14-B Post-operative result

A nasal feeding tube is passed into the stomach A large muscle rotation flap is now created (see Fig 12) The opposite sternothyroid, thyrohyoid muscle is dissected free from the larynx and trachea and from the hyoid bone The flap can now be rotated, and a thick split thickness skin graft is sutured to the under surface of the muscle The muscle flap and skin graft close off the pharyngeal defect by approximating it with the constrictor muscles Uusually two or three layers of reinforcing sutures will be necessary (see Fig 13) first some material may be aspirated into the trachea, but after several days of effort all of our patients were able to overcome this handicap Once effective deglutition is established, the tracheotomy opening may be closed All of our patients have a good voice immediately

RESULTS

Fifteen patients with epiglottic carcinoma have been operated upon with unilateral neck dissection and one with a simultaneous bilateral neck dissection (see Figs 14, 15) In four other patients with lateral laryngopharyngeal wall cancer, the transhyoid approach without removal of any portion of the larynx entailed closure of the pharynx by the rotation of a muscle flap and skin graft Experiences in the entire group thus far extends to a three-and-one-half year followup period No local recurrences have resulted in the remaining larynx to date Fixation of vocal cord occurred in one instance where the arytenoid cartilage was exposed One patient died of a coronary occlusion one year after surgery, and autopsy showed no evidence of carcinoma Seven of fifteen patients had positive nodes confirmed pathologically The high frequency of metastatic nodes from epiglottic carcinoma is suggested in this small series

Secondary neck dissection has been necessary in one instance In this patient a node became palpable six months after the first operation

SUMMARY AND CONCLUSION

Fifteen patients with carcinoma of the epiglottis have been operated upon, using a technique for *en bloc* removal of the primary lesion, together with a radical neck dissection

Reconstruction of the laryngopharynx by a muscle flap and skin graft has been effective in the early rehabilitation of the patient

Preservation of the function of the true vocal cord is possible The patients can have not only a good voice and a normal airway, but also are able to swallow normally without

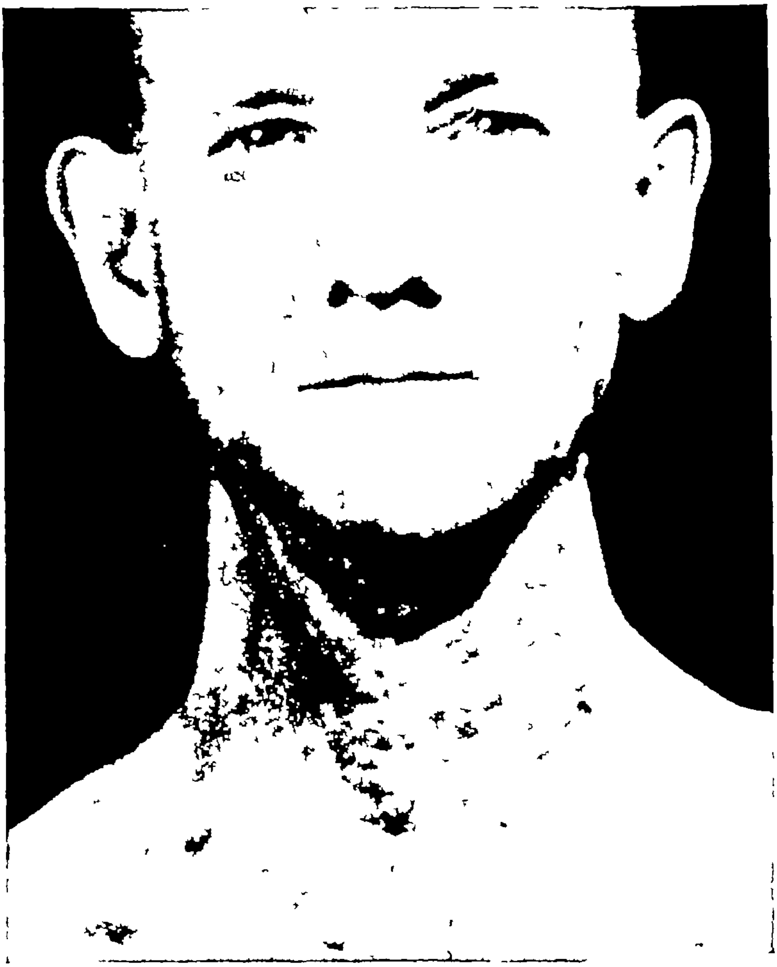

Fig 15-B Postoperative result

deglutition At first it is a conscious effort on the part of the patient, but later swallowing becomes a reflex act Thin cereal is tolerated more easily than water until the patient becomes accustomed to the sensation of the passage of food In the initial attempts at swallowing, the tracheotomy tube is closed with a cork, and the patient is told to swallow and breathe out utilizing the larynx to clear the mucous and food from the true vocal cords Usually for one small amount of food this process of clearing the throat with swallowing must be repeated several times to swallow a bolus effectively At

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POST GRADUATE COURSE IN RHINOPLASTY, RECONSTRUCTIVE SURGERY OF NASAL SEPTUM AND OTOPLASTY

An intensive post graduate course in Rhinoplasty, Reconstructive Surgery of the Nasal Septum and Otoplasty will be given July 12, 1958, to July 26, 1958, by Dr Irving B Goldman and staff at the Mount Sinai Hospital, New York, in affiliation with Columbia University

Candidates for the course should apply to Registrar for Postgraduate Medical Instruction, the Mount Sinai Hospital, Fifth Avenue and One-Hundredth Street, New York 29, New York the protective function of the epiglottis, aryepiglottic folds or false cords *

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*The author is deeply indebted to Dr Donald Chen Resident in Otolaryngology for the illustrations on the technique

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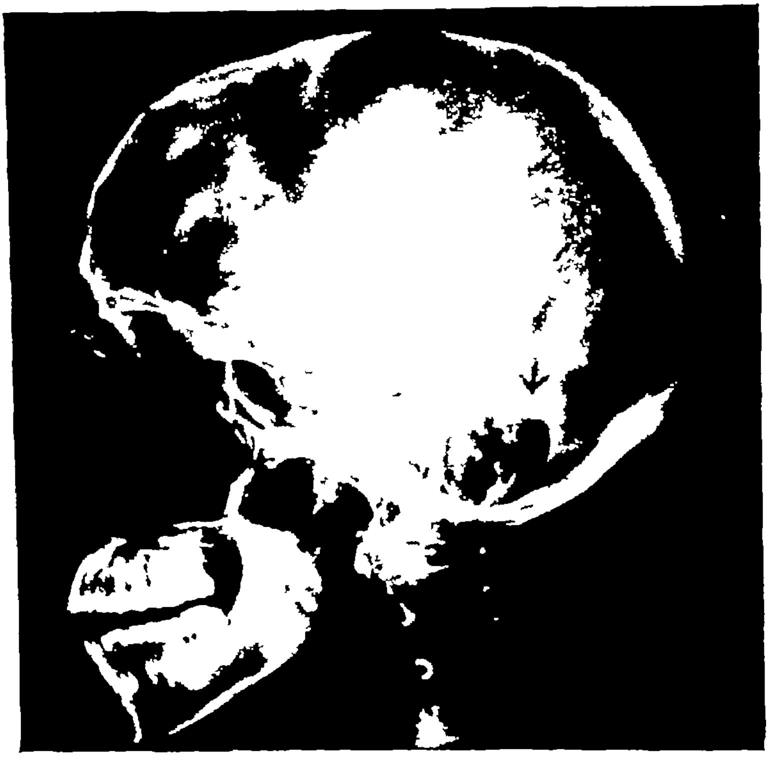

Fig 1 True cholesteatoma (epidermoid) of the left occipital and temporal bones with invasion of some of the mastoid cells but without involvement of the middle or inner ear Approximate measurement 3 5x4 5 cms Lateral view

Various medications including antihistamine and vasoconstrictor drugs were helpful only at times

On March 5 1956 the patient complained of dizziness which had been present for two or three weeks She found it difficult to describe this dizziness It was not a whirling sensation but an unsureness or a light headedness akin to giddiness It had come on without warning and did not seem to be related to her ear symptoms of 'popping" or fullness It was worse when she looked up but could be relieved by bending her head down or by chewing gum.

PSEUDO-VERTIGO FROM TRUE CHOLESTEATOMA OF THE SKULL *†

SHIRLEY HAROLD BARON, M D ,

San Francisco, Calif

True epithelial cholesteatomata originating in the cranial chamber elsewhere than in the middle ear are uncommon They represent only a fraction of one per cent of intracranial neoplasms as a whole,[1] and are seldom, if ever, thought of as a cause of dizziness An exception to the rule is the case to be reported in which skull X-rays revealed a large cholesteatoma of the left occipital and temporal bones This tumor, though *not* involving the middle or inner ear, proved to be the cause of the patient's dizziness

CASE REPORT

Mrs J , age 43, the wife of a physician, was seen first in June 1953, for an acute bilateral, suppurative, maxillary sinusitis It was not until three years later that she complained of dizziness In the interim she was seen many times

In February, 1954, she complained of a dullness and 'popping" in her right ear following an airplane trip In March, 1954, she complained of a peculiar sensation, a dullness in both ears An audiogram done then showed normal hearing There was no disease noted excepting boggy nasal turbinates suggesting a *vasomotor rhinitis* In November, 1954, the patient complained of discomfort in the left side of her face with some pain referred to the front of her left ear and a 'filling up" in both ears A week later the ear sensation had disappeared, but there was still a feeling of "something being in the left side of the nose and face This eventually disappeared

In June, 1955, the patient complained again of a feeling of fullness in both ears with intermittent "popping' and a small tender area back of her left mastoid This tenderness was thought to be due to an inflamed lymph node (The patient had some scaling *of* her scalp in this region)

On August 2, 1955, she still complained of intermittent 'popping' and fullness in her ears Examination with a nasopharyngoscope showed a small amount of lymphoid tissue above each torus and in the vault of the nasopharynx X ray therapy to the nasopharynx was suggested and then administered by a roentgenologist between August 5 and August 22

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*Read at the meeting of the Western Section American Laryngological Rhinological and Otological Society Inc Beverly Hills Calif Jan 18 1958

†From the Department of Surgery Division of Otolaryngology Stanford University Medical School and the Department of Otolaryngology Mount Zion Hospital

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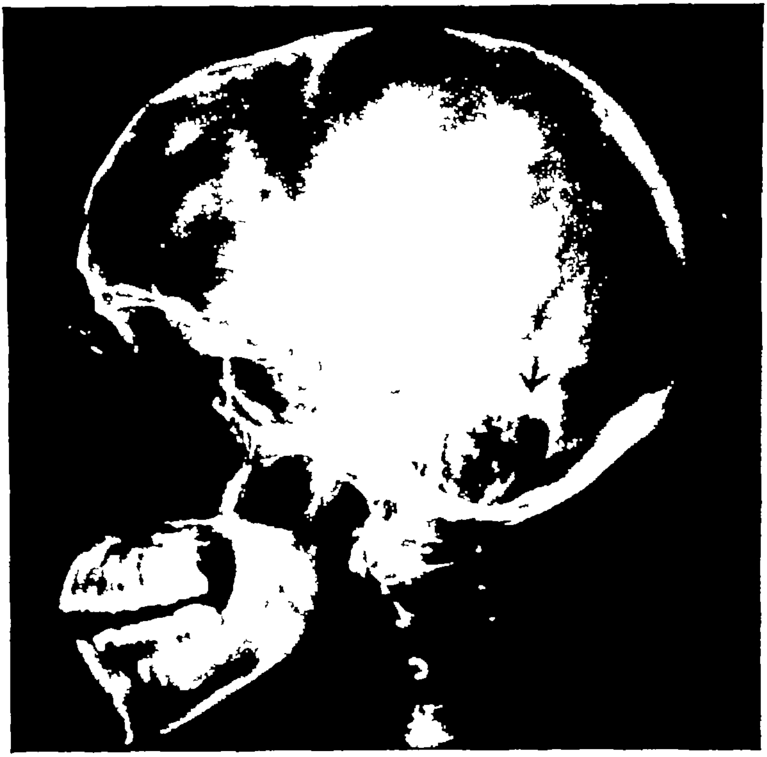

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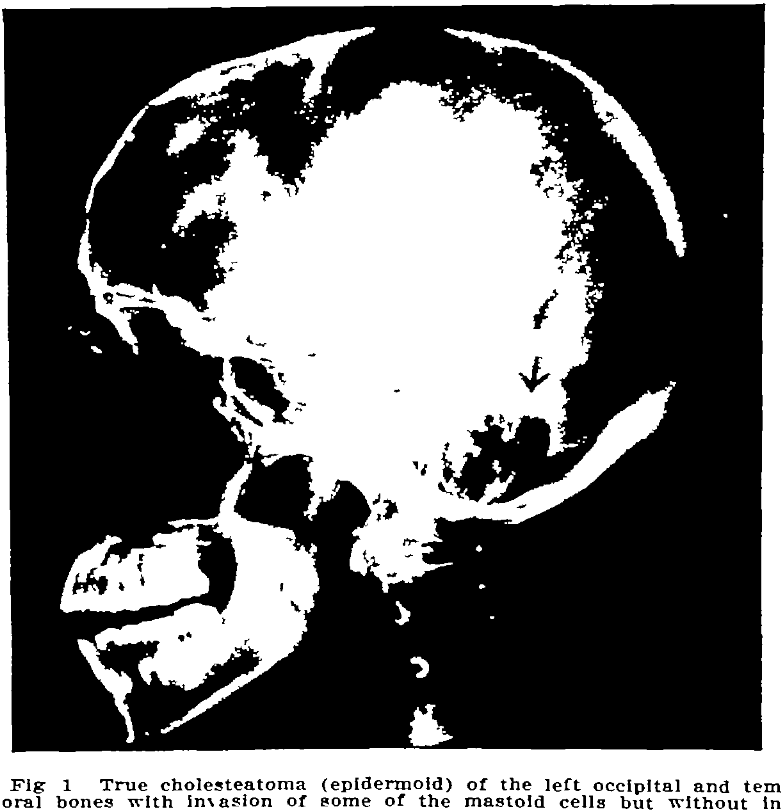

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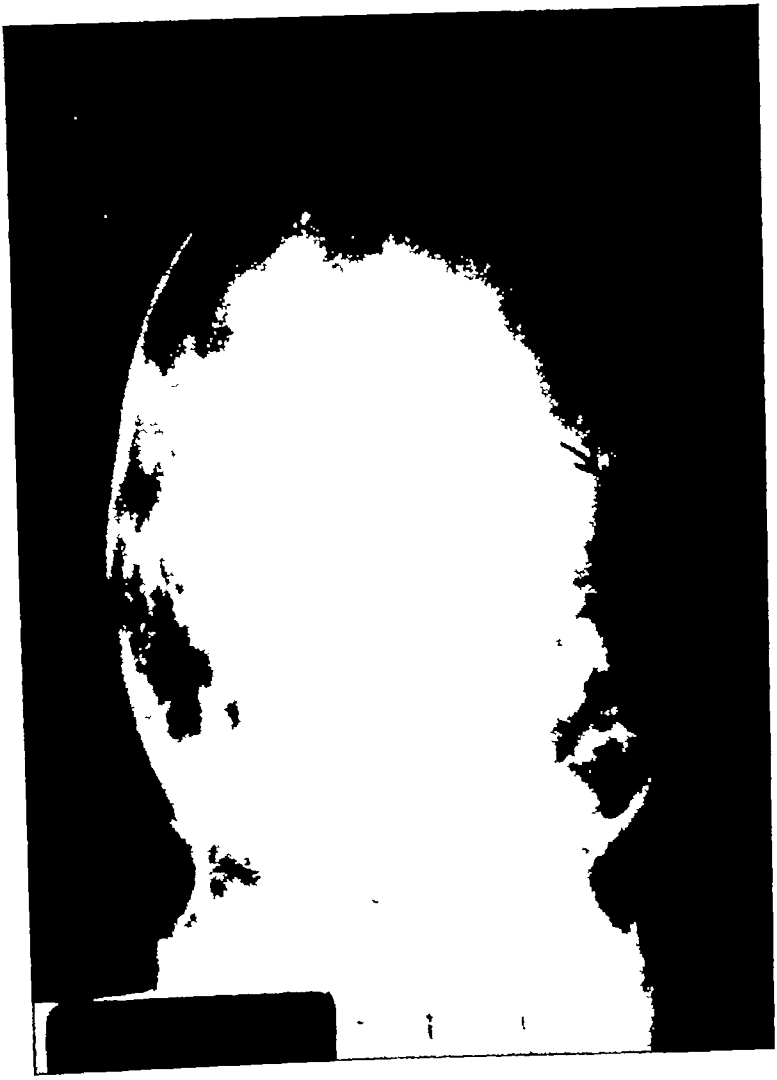


Fig 2 Same as Fig 1 sub-mento-vertical view

Examination showed no change in the appearance of the nasopharynx. The eardrum membranes were normal. The audiogram showed a slight loss in hearing for low tones in both ears (15 db at 250 and 10 db at 500 cycles per second). A cold caloric (5 cc ice water) test for vestibular function showed normal responses for both ears. A neurological examination revealed no abnormality.

The skull was X rayed. The films revealed an oval zone of diminished density involving the left occipital and temporal bones encroaching upon some of the pneumatized portion of the mastoid process but not involving the middle or inner ear. This defect measured about 3 5x4 5 cms (see Figs 1, 2) The lesion was considered to be a true cholesteatoma or epidermoid It was felt that it should be removed surgically

Surgery was done on April 2 1956 with Dr O W Jones a neurosurgeon who used a craniotomy approach over the site of the cholesteatoma A small horseshoe-shaped incision was employed the anterior limb starting at the tip of the mastoid process curving upward, then backward and down When the pericranium was reflected caudally, grumous pearly gray material characteristic of a cholesteatoma was found posterior to the tip of the mastoid process Further exposure was obtained by removing some of the outer table of the skull toward and including the occipital bone It was then possible to remove the sac of the cholesteatoma from the dura which covered the left cerebellar hemisphere and the lateral sinus The dura was compressible and transparent and about one-half inch below its surface the partially atrophic cerebellum could be seen There was fluid between the dura and the cerebellum The attachment of the tentorium had been displaced mesially

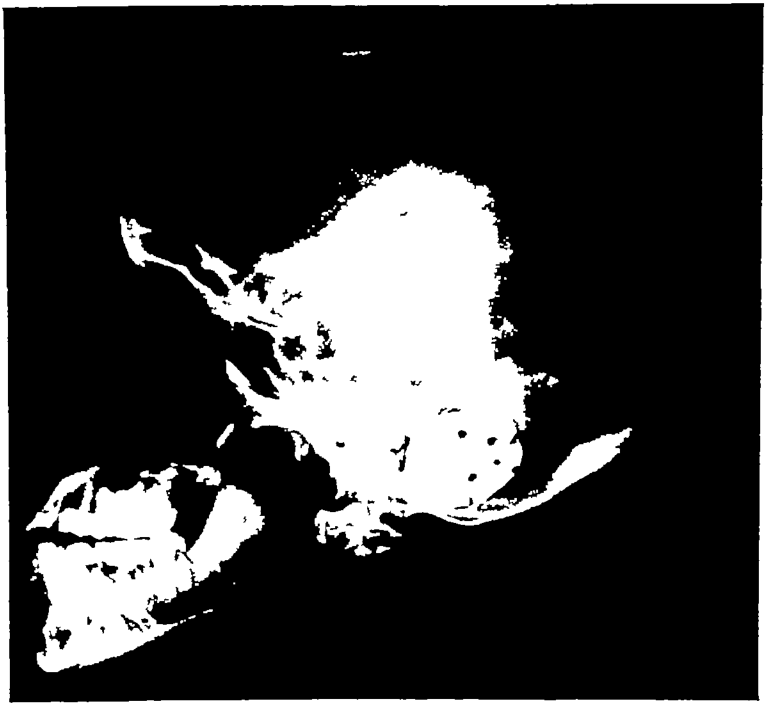


Fig 3 Tantalum plate covering the defect in the skull resulting from surgical removal of the cholesteatoma Lateral view

After Dr Jones removed the sac from the dura I removed that portion of the sac wall which had eroded the mastoid cells This was done with magnified vision and required removal of some of the underlying mastoid

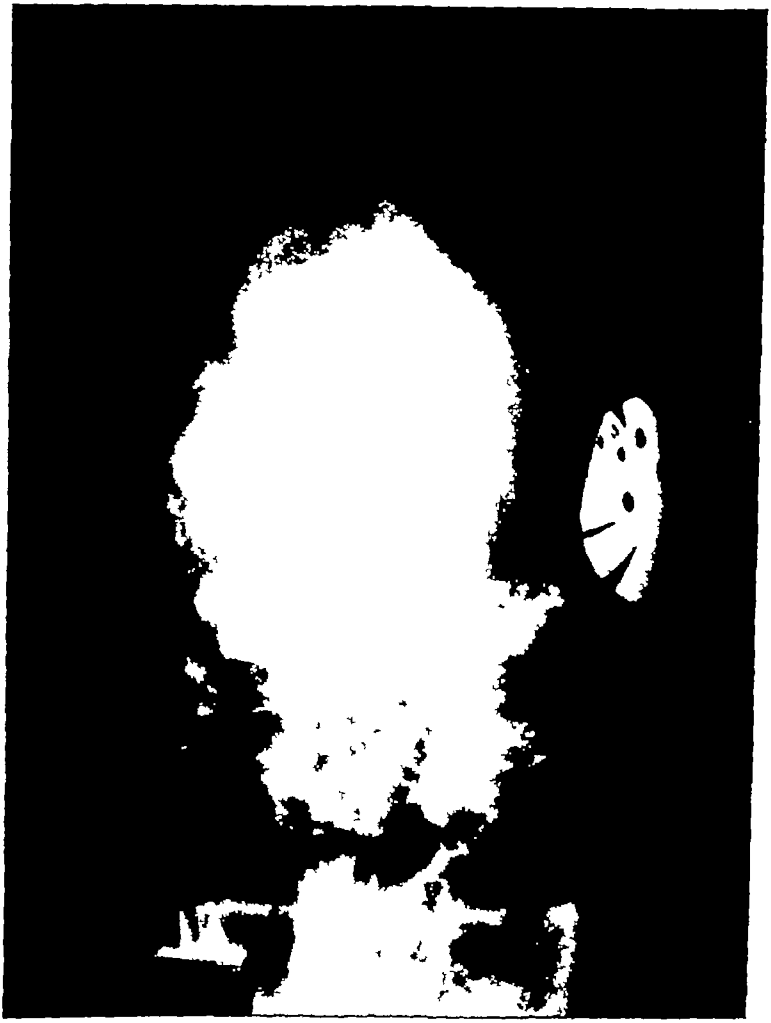


Fig 4 Same as Fig 3 sub-mento-vertical view

cells for complete elimination of the matrix When these cells were removed, the mastoid antrum came into view Its lining membrane appeared healthy and uninvolved

Gelfoam was placed into the mastoid antrum and into the defect in the mastoid cells made at surgery and by the lesion itself A tantalum plate was fashioned for the defect in the skull and held in place with two sutures of tanalum wire (see Figs 3 4) The scalp was closed, layer by layer, with sutures of nylon

The course was uneventful The left tympanic membrane examined the day after surgery, showed the bluish color of a moderate hemotympanum, which disappeared within four weeks There was a feeling of fullness, but not of deafness The sutures were removed on the fourth postoperative day The patient was dismissed on the next day

The dizziness disappeared following surgery and has not recurred to date The patient has complained of a sensation of an echo in her left ear but feels that her hearing is normal She still experiences 'popping" in both ears An audiogram done on June 14 1957, revealed a slight loss of hearing as compared with that of February, 1954, but the slight loss was about equal for both ears The readings were for the right ear 250 20, 500 10 1000-0, 2000 5 4000 10, 8000 15, for the left ear 250 25 500 10, 1000 minus 5 2000 10, 4000 10 8000 5

COMMENT

The discovery of such a large lesion of the skull in this patient the wife of a physician after she had been under my care for three years was a bit embarrassing for, considering its size, the cholesteatoma must have been present all of those three years probably longer, yet in retrospect, there was nothing that suggested an indication for X rays of the skull until the symptom of dizziness appeared

The use of nasopharyngeal irradiation, worthless to this patient merits criticism This is self-criticism and criticism of others who have developed the habit of resorting to irradiation therapy as a crutch for the patient with tubal symptoms when no other treatment seems available Irradiation therapy in patients with more defined tubal symptoms has proven disappointing in my experience so certainly there was little excuse for my having suggested it here

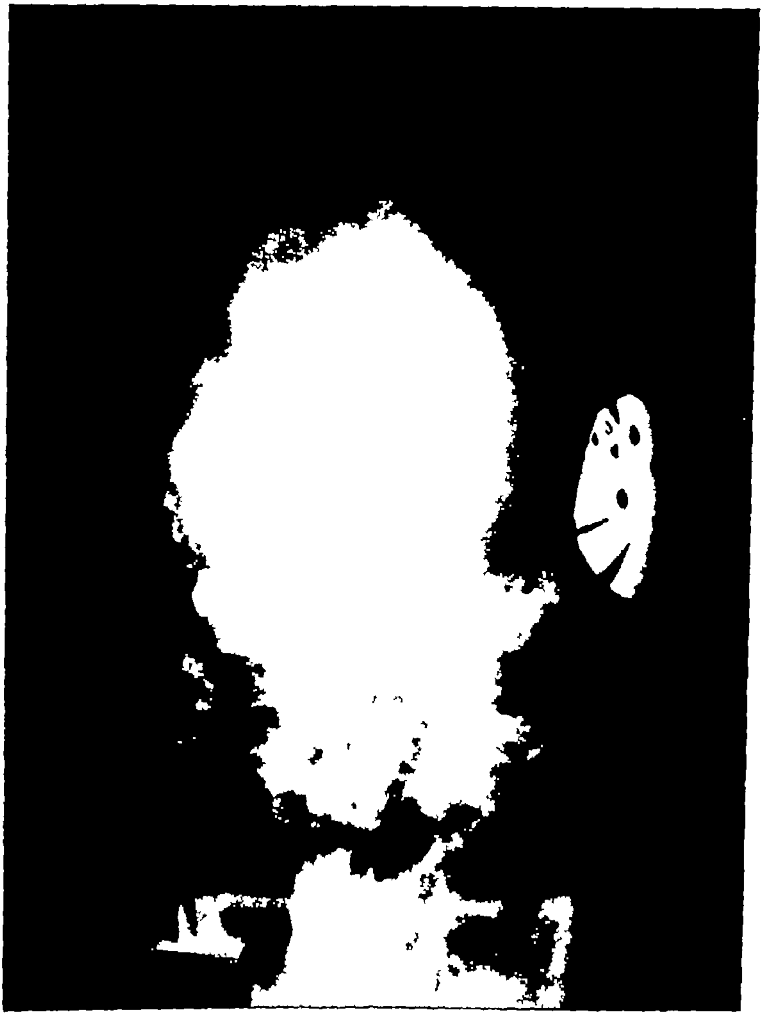
The sensation of an echo in the left ear is difficult to explain The alteration in the mastoid air cell system could hardly be considered a cause in view of the fact that an echo sensation does not exist in those patients who have had mastoidectomies which result in a much greater alteration in the mastoid anatomy

It is unlikely that the intermittent ear popping is related to the skull cholesteatoma It is probably the result of the vasomotor instability of this patient

DISCUSSION

Since there occasionally exists some confusion in the terminology of the classification of cholesteatomata, it might be worth while to review Wittmaack's[3,4] classification, which is generally used Sometimes the terms "true cholesteatoma" and "primary cholesteatoma" are used interchangeably, but incorrectly so Recently Day[5] titled a paper, "A Primary Cholesteatoma of the Middle Ear," but in the text of his article he referred to the lesion as a "cholesteatoma verum" or a true congenital cholesteatoma The incorrect use of "primary" in this instance was probably an oversight

A cholesteatoma is a tumor which is surrounded by a thin shell of epidermis and connective tissue in which is accumulated desquamated horny epithelium Wittmaack classified



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The more common situations of a true cholesteatoma are *1* in and about the temporal bone, *2* in the leptomeninges of the cerebral base, *3* in the cerebral ventricles, these last being endothelial tumors, and *4* in the bones of the skull at places remote from the middle ear, such as the occipital, parietal or frontal bone The latter are of the epidermoid variety alone and seem to originate between the two tables of the skull, the inner table being the first one to become ballooned out and absorbed as the growth enlarges Such a tumor is represented by the lesion found in the case reported

Cushing ventured the opinion that true cholesteatoma rather than pseudocholesteatoma may be the rule in the middle ear cholesteatomas, and that the cholesteatoma is responsible for the otitis media rather than the reverse Except for the primary type of pseudocholesteatoma, it is unlikely that any otologist would support Cushing's view

Pseudocholesteatoma The primary, or genuine type is thought to come from a spontaneous perforation of Shrapnell's membrane The perforation itself is the result of marked epitympanal absorption of air from a shutting of the tubotympanic space by adhesive bands that are thought to occur in the course of otitis neonatorum From the margins of the perforation epithelium invades the attic of the tympanum (epitympanum) and the antrum of the mastoid process and, with the accumulation of the trapped products of desquamation, the pseudocholesteatoma gradually enlarges, causing pressure rarefaction of the underlying bone This type usually is seen only when secondary suppuration occurs, or when complications arising from increased intracranial pressure cause death They have been discovered during life as the result of a search for the cause of progressive deafness in certain patients

The secondary type of pseudocholesteatoma is the sequel of a chronic otitis media in which the epithelium from the external auditory canal, or from the margin of the tympanic cholesteatomas into two main types *1* true cholesteatoma, and *2* pseudocholesteatoma The pseudocholesteatomas are divided into *a* the primary, or genuine, type, and *b* the secondary type

True Cholesteatoma This tumor is considered to be derived from an embryonic rest and consists of concentric polygonal lamella, composed of epidermoid cells which are devoid of nuclei Between these lamellas are found cholesterol crystals in greater or lesser quantity Surrounding the mass is a membrane, the cholesteatoma matrix, which has an outer layer of connective tissue attached to bone, and an inner epidermal layer These are referred to in Bancroft[6] as "epidermoids" He states, "Epidermoids, sometimes loosely called 'cholesteatomas,' occasionally arise in the diploe of the skull The lesions are congenital and are really cysts lined with squamous epithelium and entirely filled with flaky white epithelial debris"

There is no recognizable difference pathologically between the "true" and the "pseudo" cholesteatoma

The true cholesteatoma, also known as pearly tumor, is found in the skull, not usually associated with the ear

Cushing,[1] in 1922, in a very excellent article, associated the names of Cruveilhier, Johannes Mueller and Virchow with the true cranial or intracranial cholesteatoma, and credits Cruveilhier with coining the name "pearly tumor"

Cushing stated, "The cholesteatomata remote from the temporal bone are unusual tumors, and certain types of them excessively so They are so uncommon, indeed, and excite so much interest when disclosed unexpectedly postmortem, or more rarely in the course of an operation on the brain, that they are prone to find their way into medical literature So far as I am aware, the condition has never been diagnosed except at autopsy or operation Certain of these lesions, however, despite their obscurity, should be quite capable of recognition because of the characteristic changes in the bone which the X-ray may disclose"

Cushing reported an interesting case of a very large choles-

REPORT OF A RECENT STUDY ON DIHYDROSTREPTOMYCIN OTOTOXICITY *†

ARAM GLORIG, M D ,

Los Angeles, Calif

INTRODUCTION

The ototoxicity of streptomycin (SM) and dihydrostreptomycin (DHSM) has been recognized since 1946 Soon after streptomycin first became available for therapeutic purposes untoward effects centering mainly around the vestibular system were noticed Attention was directed towards these effects by patients' subjective complaints of vertigo, loss of visual focus, imbalance, slight sensations of nausea and even spontaneous nystagmus On the strength of these complaints and at the suggestion of Dr Edmund P Fowler, Jr , the author conducted a study designed to determine the extent and location of the lesion apparently produced by streptomycin The results of the study were reported in 1947 in the *Annals of Otology, Rhinology and Laryngology*

Shortly after the completion of this first study, about 1948 or 1949, there appeared on the market a modification of streptomycin called dihydrostreptomycin When dihydrostreptomycin was used as a therapeutic agent, complaints related to vestibular pathology were less numerous Dihydrostreptomycin seemed to be less toxic than streptomycin We were soon to discover, however, that the one set of symptoms were replaced with another Instead of showing vestibular symptoms, numerous patients began to show evidence of hearing loss This was indeed a complete change It was somewhat of a surprise and, at first, quite unbelievable Some of the patients began to have difficulty communicating when spoken

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†Research Center Subcommittee on Noise in Industry Los Angeles Calif

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membrane, invades the middle ear or the epitympanum and the antrum of the mastoid process It progressively increases in size in the pattern described for the *primary type* of pseudocholesteatoma

SUMMARY

A report of a patient having had a form of dizziness caused by a true cholesteatoma of the skull has been presented This tumor was situated in the left occipital and temporal bones with invasion of some of the mastoid cells but without involvement of the middle or internal ear The origin of this cholesteatoma was probably in the diploe of the occipital bone

This patient's dizziness, a pseudo-vertigo, was cured by the surgical removal of the cholesteatoma The surgical technique has been described with the aid of slides of photographs in color taken during the surgery

The dizziness undoubtedly was caused by pressure of the cholesteatoma upon the left hemisphere of the cerebellum, which evidenced some atrophy (as seen through the transparent dura) at the time of surgery Apparently the surgical relief of this pressure permitted the return of function

CONCLUSION

True cholesteatoma of the skull without involvement of the middle or inner ear must be added to the list of possible causes of the varied forms of dizziness

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516 Sutter Street

widespread published support for the belief that streptomycin is much more toxic to the vestibular apparatus than is dihydrostreptomycin, and that dihydrostreptomycin is more toxic to the auditory system than is streptomycin In general the recent articles also confirm earlier estimates of the amount of drug necessary to produce toxic effects Specifically, in the case of streptomycin, if 1 to 2 gms per day are used, vestibular symptoms will usually occur in three to four weeks If the dosage is limited to 1 gm twice a week the appearence of symptoms is delayed considerably The time of appearance of symptoms seems to be directly related to the total amount of drug used, and it also appears to be dependent upon the amount of time between doses

Similar statements can be made about dihydrostreptomycin and its effect on the cochlear division of the VIIIth nerve The hearing losses produced by dihydrostreptomycin are usually bilateral They are primarily in the upper frequencies unless severe losses occur, in which event the speech frequencies also are affected Most of the studies indicate that 10 to 15 per cent of patients treated with dihydrostreptomycin sustain a hearing loss after the total dose reaches 50 to 60 gms

One point is very clearly made in most of the reports when renal insufficiency exists, the toxic effects of the drug are increased, and more severe hearing loss results This is to be expected, as streptomycin and dihydrostreptomycin both are secreted by way of the kidney, and renal insufficiency, therefore, raises the blood levels considerably above that found in patients with normal renal function, and causes increased ototoxicity

Early in the course of the studies of dihydrostreptomycin and streptomycin ototoxicity, there was some disagreement about the location of the lesion This author maintained in 1947 that because of the selectivity of the toxic effects for higher frequencies, the lesion is a peripheral one It was, and it still is, difficult for me to see how a selective hearing loss in specific frequencies can be caused by any pathology proximal to the organ of Corti I am happy to report that the to in a loud voice, however, and it became apparent that further research to determine the ototoxic effects of dihydrostreptomycin was needed With the cooperation of the tuberculosis department at the Gallenger hospital and the medical division of George Washington University in Washington, D C , the author conducted a study to determine the amount of hearing loss produced in patients treated with dihydrostreptomycin This study was reported in the *Annals of Otology, Rhinology and Laryngology* in 1951

On the basis of the results of these two studies, the following conclusions were drawn

1 Dosages of 1 to 2 gms of streptomycin per day administered for periods of more than 45 to 50 days may produce complete loss of the labyrinthine function in many patients

2 If the same regime as (1) is followed with dihydrostreptomycin, some 20 to 25 per cent of patients will sustain considerable hearing loss, particularly in the frequencies from 3000 to 8000 c p s

3 Any patient receiving streptomycin and particularly dihydrostreptomycin should be tested routinely for changes in vestibular and auditory function If dihydrostreptomycin is used, the hearing tests should be continued for at least six to nine months after treatment has stopped, because many cases developed hearing losses after treatment had been discontinued

4 Because streptomycin affects the vestibular system primarily, it should be the drug of choice Many patients will compensate for loss of vestibular function, but there is no satisfactory way to compensate for hearing loss

LATER STUDIES

A review of the recent literature revealed that the conclusions stated above are still valid Reports by Anderson in the *Journal of Laryngology and Otology,* Lidén in *Acta Oto-laryngologica* Cawthorne in the *British Medical Journal,* and Hawkins et al in the *Antibiotics Annual* of 1956-57, confirm the results of studies made prior to 1953 There is

Prior to the therapy, each patient was tested in a quiet room with a standard audiometer at 500, 1000, 2000, 3000, 4000 and 6000 cycles per second He was then tested twice a week for four to six weeks during the early part of the study After this initial schedule was completed, each patient was tested once a week for approximately 90 to 100 days and then once every two weeks until discharged or lost to the study for one reason or another (see Table I)

TABLE I

Number of Audiograms Per Patient.

No Patients	No Audiograms
100	1103
17	6-12
19	18-26
14	28-58
Least per patient	6
Most per patient	58

TABLE II

Amount of Antibiotic Administered to Date of Report

Patients treated with DHSM (N = 51)			Patients treated with DIDRO (N = 49)	
No with no shift	No with shift	No Grams	No with no shift	No with shift
3	0	1 24	3	0
12	0	25- 49	1	0
4	2	50- 74	8	1
3	1	75 99	5	1
10	3	100-124	11	6
3	1	125 149	2	2
5	1	150-174	3	4
2	1	175-199	0	0
0	0	250-274	0	0
0	0	401	1	1
42	9		34	15

Fifty-one of the patients received 1 gm of dihydrostreptomycin per day, and 49 received 1 gm of didrothenate per day Of the 51 patients receiving dihydrostreptomycin, nine showed an elevation in their auditory thresholds, and of the 49 patients receiving didrothenate, 15 showed an elevation in their auditory thresholds Table II shows how many of the general conclusion now is that the lesion is undoubtedly in the end-organ, both in the case of the vestibular apparatus and the hearing mechanism.

RECENT DEVELOPMENTS

A recent report of great interest to those of us concerned with the ototoxicity of these antibiotics stated that when pantothenic acid is added to streptomycin or to dihydrostreptomycin, treatment is accompanied by less toxicity. Several German workers, Keller et al. in particular, reported in April, 1956, that considerably less toxicity resulted in animals treated with either streptomycin or dihydrostreptomycin in combination with pantothenic acid. Several studies were conducted in the United States, notably by Hawkins in 1956-57, to check the validity of the German claim. None of these studies confirmed the German conclusions

Much of the research into the effects of pantothenic acid combinations has been done with animals, particularly cats and mice Because it appeared that pantothenic acid combinations might be less toxic in animals, the Lederle Company, in cooperation with the Department of Medicine, University of California at Los Angeles, requested that a study be conducted under my supervision to compare in human subjects the effects of the pantothenic acid combination called didrothenate (DIDRO) with the effects of regularly available dihydrostreptomycin. It was agreed that tuberculous patients would be used and that equal numbers would be treated with standard dihydrostreptomycin and didrothenate specially prepared by Lederle for experimental purposes In this way the toxicity of the drugs could be compared under controlled conditions

PRESENT STUDY.

A total of 149 patients started in the program, but only 100 of them are considered in this paper The remaining 49 patients were excluded from the analysis, because they were discharged from the hospital for one reason or another before they had received enough drug to be of use in the study

Prior to the therapy, each patient was tested in a quiet room with a standard audiometer at 500, 1000, 2000, 3000, 4000 and 6000 cycles per second He was then tested twice a week for four to six weeks during the early part of the study After this initial schedule was completed, each patient was tested once a week for approximately 90 to 100 days and then once every two weeks until discharged or lost to the study for one reason or another (see Table I)

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No with no shift	No with shift	No Grams	No with no shift	No with shift
3	0	1- 24	3	0
12	0	25- 49	1	0
4	2	50 74	8	1
3	1	75 99	5	1
10	3	100 124	11	6
3	1	125 149	2	2
5	1	150 174	3	4
2	1	175-199	0	0
0	0	250 274	0	0
0	0	401	1	1
42	9		34	15

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Comparisons of the amount of threshold shift in db at 1000 c p s in the right ear show that two of the patients on dihydrostreptomycin acquired shifts of 5 to 15 db and five of those on didrothenate showed a similar threshold shift At 4000 c.p s in the right ear, one patient on dihydrostreptomycin and four on didrothenate showed a 5 to 15 db threshold shift

TABLE III

Number of Patients with Threshold Shifts of 5 15 db , 20 30 db , 35 50 db

			Number of patients with shift at indicated frequency (c p s)					
Threshold Shift (db)	Antibiotic	Ear	500	1000	2000	3000	4000	6000
5 to 15	DHSM	R	3	2	2	1	1	1
5 to 15	DHSM	L		2	2		3	1
5 to 15	DIDRO	R	5	5	3	3	4	5
5 to 15	DIDRO	L	3	4	3	4	5	6
20 to 30	DHSM	R			1			2
20 to 30	DHSM	L	1	1	2	1	1	1
20 to 30	DIDRO	R				2		4
20 to 30	DIDRO	L			1			2
35 to 50	DHSM	R			1	2	1	1
35 to 50	DHSM	L					1	1
35 to 50	DIDRO	R					1	1
35 to 50	DIDRO	L				1		1

Threshold measurements of the left ears show that two of the patients on dihydrostreptomycin sustained from 5 to 15 db shift at 1000 c p s and four of those on didrothenate showed the same shift Again when the shifts are measured at 4000 c p s in the left ear, three of the patients on dihydrostreptomycin showed from 5 to 15 db shift and 5 of those on didrothenate had the same shift (see Fig 1)

At 1000 c p s only one of the 100 patients acquired a shift greater than 15 db on either drug At 4000 c p s none showed a shift of 20 to 30 db on either drug in the right ear In the left ear, however, one person treated with dihydrostreptomycin showed a shift of 20 to 30 db (see Fig 2), also at 4000 c p s, two of the patients on dihydrostreptomycin showed shifts of 35 to 50 db, one in the right ear and one in the left (see Fig 3)

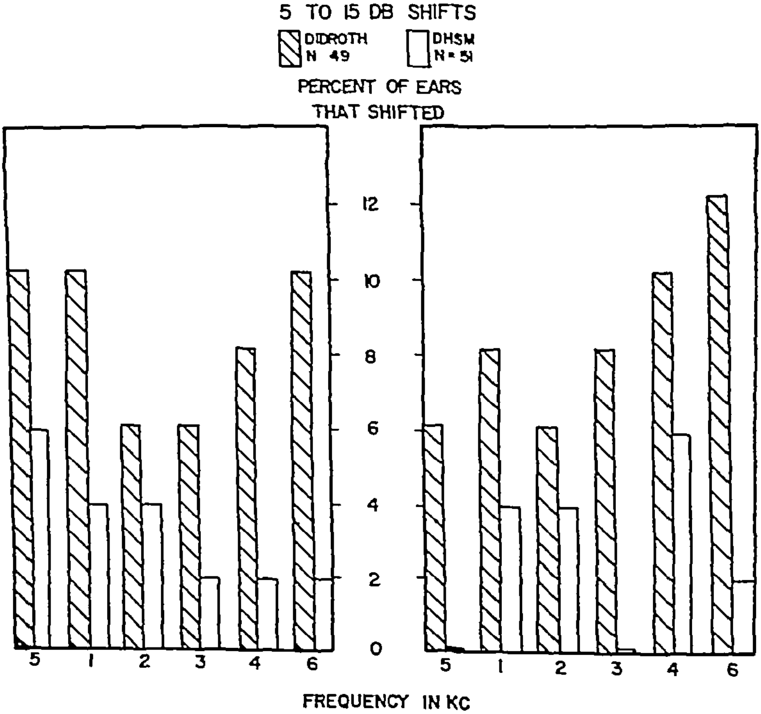

Fig 1

Threshold shifts were compared at 1000 and at 4000 c p s, because losses at 1000 c p s reflect the amount of handicap for communication by speech and losses at 4000 c p s represent the maximum losses usually found in the high frequencies

There were no threshold shifts at the speech frequencies in excess of 30 db when either antibiotic was used On the basis of this, we can assume that no patient will sustain a significant hearing loss as a result of treatment if he has normal persons in the total group exhibited an elevation in threshold, and the number of grams of dihydrostreptomycin or didrothenate the "shifters" had received Table III shows the number of persons who acquired threshold shifts of 5 to 15 db, 20 to 30 db, and 35 to 50 db, at each of the frequencies tested

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Threshold Shift (db)	Antibiotic	Ear	Number of patients with shift at indicated frequency (c p s) 500	1000	2000	3000	4000	6000
5 to 15	DHSM	R	3	2	2	1	1	1
5 to 15	DHSM	L		2	2		3	1
5 to 15	DIDRO	R	5	5	3	3	4	5
5 to 15	DIDRO	L	3	4	3	4	5	6
20 to 30	DHSM	R			1			2
20 to 30	DHSM	L	1	1	2	1	1	1
20 to 30	DIDRO	R				2		4
20 to 30	DIDRO	L			1			2
35 to 50	DHSM	R			1	2	1	1
35 to 50	DHSM	L					1	1
35 to 50	DIDRO	R					1	1
35 to 50	DIDRO	L				1		1

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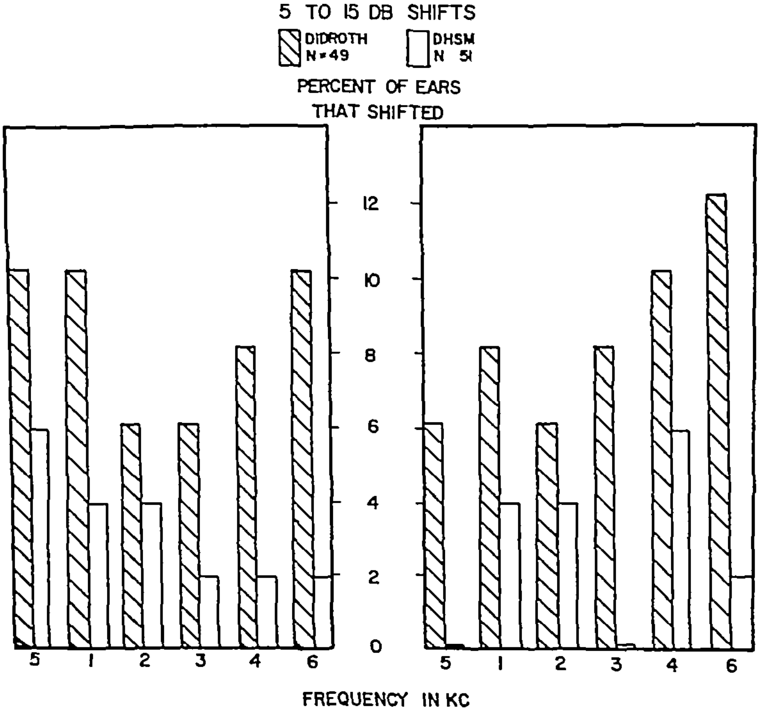

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Threshold shifts were compared at 1000 and at 4000 c p s, because losses at 1000 c p s reflect the amount of handicap for communication by speech and losses at 4000 c p s represent the maximum losses usually found in the high frequencies

There were no threshold shifts at the speech frequencies in excess of 30 db when either antibiotic was used On the basis of this, we can assume that no patient will sustain a significant hearing loss as a result of treatment if he has normal hearing when the antibiotic is started Allowing for a reasonable amount of expected variation in audiometry, some 10 db , that is, we judge that only a relatively small per cent of the shifts are significant Only two ears on dihydrostreptomycin and one on didrothenate showed shifts greater than 10 db at 1000 c p s

At 4000 c p s , we find that only three ears in the didrothenate group show more than 10 db shift and that only five ears in the dihydrostreptomycin group show more than 10 db shift When reduced to percentage, these figures are 3 per cent and 4 9 per cent respectively

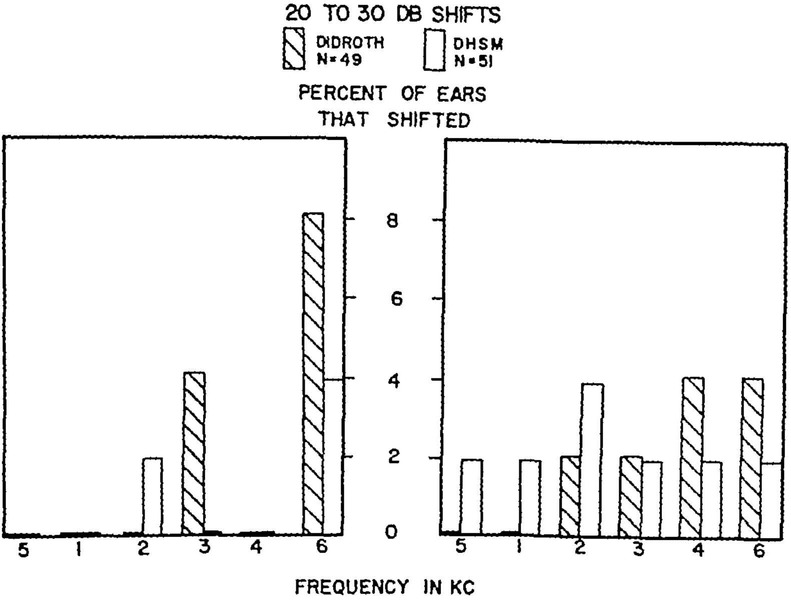

Fig 2

As for losses in excess of 30 db at 4000 c p s , we find that one ear shifted 40 db when didrothenate was used and when dihydrostreptomycin was used, one ear shifted 50 db , and another 40 db If all ears that shifted more than 10 db at any frequency are lumped together, there are 20 in the group treated with didrothenate and 23 in the group treated with dihydrostreptomycin If we look for ears showing losses greater than 30 db at any frequency, we find that there are only four with shifts of this magnitude in the group treated with didrothenate and eight in the group treated with dihydrostreptomycin (see Table III)

The significance of the magnitude of threshold shift to the patient must be evaluated from the final audiogram In other words, is the change in hearing level enough to cause handicap? Table IV shows the number of patients whose

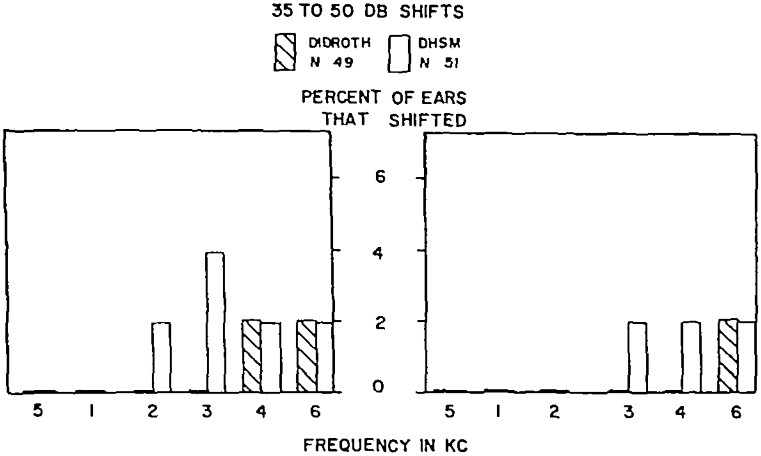

Fig 3

thresholds at 1000 and 4000 c p s lie between 5 to 15 db, 20 to 30 db, 35 to 50 db, 55 to 70 db, and above 75 db Only one ear shows a hearing level greater than 30 db at 1000 c p s This case was treated with dihydrostreptomycin

To assess the amount of handicap resulting from the hearing losses acquired during this study, let us compare the beginning hearing level with the final hearing level of ears that show less than 20 db at 1000 and 2000 c p s prior to treatment and more than 20 db at 1000 and 2000 c p s at the time of this report There is only one such case at 1000 c p s in both ears, three cases, two with bilateral losses, and one with a unilateral loss at 2000 c p s , in the group treated with dihydrostreptomycin In the group treated with didiothenate, we find no cases at 1000 c p s and at 2000 c p s , three cases with bilateral losses

Table V shows the number of grams of antibiotic administered to cases whose hearing level on the pre-treatment audiogram was less than 20 db at 1000 and 2000 c p.s and on the post-treatment audiogram was greater than 20 db Note the similarity in dosages of dihydrostreptomycin and didiothenate

TABLE IV

Final Threshold of Patients Showing an Elevation at 1000 and 4000 c p s

Hearing Level in db	Antibiotic Used	Right Ear 1000 c.p s No Cases	Right Ear 4000 c p s No Cases	Left Ear 1000 c p s No Cases	Left Ear 4000 c p s No Cases
5 15	DHSM	8	4	6	2
5 15	DIDRO	13	4	12	2
20 30	DHSM	3	2	4	1
20 30	DIDRO	2		3	2
35 50	DHSM		2	1	2
35 50	DIDRO		5		5
55 70	DHSM		3		2
55 70	DIDRO		4		4
75+	DHSM				3
75+	DIDRO		2		2

TABLE V

Amount of antibiotic used when threshold shift first appeared and total amount administered to date to patients whose thresholds at 1000 and 2000 c p s were less than 20 db pre treatment and more than 20 db post treatment

Case	DHSM No Gms When Shift Started	Total Dose	Case	DIDRO No Gms When Shift Started	Total Dose
A	125	186	A	19	150
B	42	54	B	168	258
C	130	138	C	46	84

Let us now consider an average of the post-treatment thresholds at 500, 1000 and 2000 c p s in the better ear If we assume than the hearing loss is significant when this average is 30 db or more, only one patient treated with dihydrostreptomycin and none treated with didrothenate showed a significant hearing loss (see Table VI)

DISCUSSION

You will no doubt remember that we started out to determine whether, in a group of 100 tuberculous patients, didrothenate (the pantothenic acid salt of dihydrostreptomycin) exhibited less ototoxicity than did dihydrostreptomycin Let me hasten to make clear than 100 total cases in this kind of study are enough only to establish trends We cannot draw conclusions about the magnitude of hearing loss that will result from a given treatment The trends are quite clearly evident, however, and I feel sure that additional studies will confirm them

TABLE VI

Number of Patients with Significant Hearing Loss After Treatment (average of 30 db or more at 500 1000 and 2000 c.p.s)

DHSM	DIDRO
1	0

If we compare the two treatments generally on the basis of amount of shift produced, we find more patients with shifts greater than 30 db in the dihydrostreptomycin group Consider in more detail the magnitude of threshold shift in terms of the amount of antibiotic received by the patient The data in Table II indicate that out of 22 patients who received less than 100 gms of Dihydrostreptomycin, only three showed any increase in elevation of their auditory threshold These data also show that out of 17 patients who received less than 100 gms of dihydrostreptomycin, only two showed an increase in elevation of their auditory threshold There were 20 patients who received between 100 and 200 gms of dihydrostreptomycin and six showed an increase in threshold level Sixteen patients received between 100 and 200 gms of didrothenate and 12 showed an increase in threshold

These comparisons seem to indicate that didrothenate is more toxic than dihydrostreptomycin From Table III, however, you will note that most of the threshold shifts in the didrothenate treated group are 10 db or less That is, they fall within our arbitrary limits of expected audiometric variability and cannot, therefore, be related to ototoxicity Comparisons of magnitudes of shift would seem to indicate that dihydrostreptomycin is more toxic than didrothenate The apparent difference, however, could be due to the smaller amount of dihydrostreptomycin contained in didrothenate One gram of didrothenate contains less dihydrostreptomycin than one gram of pure dihydrostreptomycin

When the results of this study are compared with those of my 1951 study, there appears to be a marked change in ototoxicity of dihydrostreptomycin In spite of the larger daily dosage received by some of the patients in the earlier study, there are significant differences in the amount of threshold shift that indicate much less ototoxicity from the dihydrostreptomycin that is available today Specifically

1 There were no cases of profound deafness in this series

2 Only one case treated with dihydrostreptomycin and none treated with didrothenate had a final average hearing level greater than 30 db at 500, 1000 and 2000 c p s

3 No positive conclusions can be drawn regarding vestibular effects, since no vestibular tests were performed There were no symptoms of vestibular dysfunction, however, and we assume that there were no significant vestibular changes

In contrast to these findings, the 1951 study included one case of profound deafness, also, out of the 40 cases treated with 1 gm of dihydrostreptomycin per day for periods comparable to those reported in this study, 14 or 35 per cent showed losses in excess of 30 db throughout the audiometric frequency range About half of the impaired hearing cases showed vestibular dysfunction symtomatically and with caloric tests

Why there is such an apparent decrease in dihydrostreptomycin ototoxicity is difficult to say It is possible that present day manufacturing processes produce a purer and, therefore, less toxic product, but the manufacturers have been questioned about this, and they are not aware of any changes in purity

In view of some recent reports, we might well ask ourselves whether today's dihydrostreptomycin really is less toxic During the past two or three years, there have been numerous oral and written reports of sudden increases in the auditory threshold of patients on small doses of dihydrostreptomycin, and combinations containing dihydrostreptomycin These small doses vary from 1 to 10 grams In light of our present study, it is difficult to explain these losses The facts seem to be in order, however, the losses are real and the causal relations appear well founded In my opinion, there can be only one explanation—individual sensitivity to dihydrostreptomycin Such sensitivity is not restricted to the mycin preparations We have known for many years that ototoxicity may result from quinine, aspirin, nicotine, etc. It is not unreasonable to assume that with more widespread general use of streptomycin and dihydrostreptomycin singly and in combination with broad spectrum preparations, we will be treating an increasing number of susceptible individuals

CONCLUSIONS

The conclusions that I wish to draw from this study are

1 A comparison of hearing losses produced in patients treated with didrothenate and patients treated with dihydrostreptomycin definitely shows that didrothenate is not significantly less toxic than dihydrostreptomycin

2 When the results of this study are compared with the results of previous studies, not only is the number of persons who show an elevation of threshold smaller in this study, but also the amount of threshold shift is considerably less

3 When compared with my previous investigations the results of this study indicate that now larger total doses of these antibiotics can be administered before an elevation in the auditory threshold level appears

4 Streptomycin is still the preferable antibiotic It is better to lose vestibular function than to lose auditory function

SUMMARY

Audiometric data from tests of 100 tuberculous patients treated with dihydrostreptomycin and didrothenate (the pantothenic acid salt of dihydrostreptomycin) are presented Fifty-one of the 100 cases received 1 gm of dihydrostreptomycin per day and 49 received 1 gm of didrothenate per day Nineteen of the patients received total doses of 25 to 99 gms of dihydrostreptomycin, 14 of them received 25 to 99 gms of didrothenate Twenty of these patients received 100 to 199 gms of dihydrostreptomycin Sixteen of them received 100 to 199 gms of didrothenate One received 258 gms of didrothenate and another 401 gms of didrothenate One person in the dihydrostreptomycin group showed a clinically significant hearing loss There were no clinically significant losses in the didrothenate group The majority of threshold shifts occurred at frequencies above 2000 c p s

RECOMMENDATIONS

Five important precautions that can be used to safeguard against dihydrostreptomycin toxicity are

1 Where either dihydrostreptomycin or streptomycin is indicated, streptomycin should be used There is no contraindication to this procedure Dihydrostreptomycin has never been shown to be better therapeutically

2 When broad spectrum antibiotics are used in combination with streptomycin or dihydrostreptomycin, the combination used should contain streptomycin, not dihydrostreptomycin

3 The manufacturers of combined antibiotics should be required to state clearly which antibiotics are contained in the combination preparations

4 Where long term treatment with streptomycin is contemplated, vestibular and auditory tests should be given routinely

5 When short term treatment is contemplated, that is, less than a total of 10 gms to be administered over a period of five to ten days, the treatment should be discontinued at the first sign of vestibular or auditory toxicity Tinnitus and slight vertigo are significant

ACKNOWLEDGMENTS

This study was made possible by a grant from the Lederle Company I thank Dr William Hewitt, Department of Medicine, U C L A School of Medicine, and Dr Stanton Hardy of the Lederle research staff for their help on this project I also thank Mr Andrell Henry, the audiologist, who did most of the hearing tests

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SEVENTH INTERNATIONAL CONGRESS OF BRONCHOESOPHAGOLOGY

The Seventh International Congress of Bronchoesophagology will be held at Kyoto (Japan) University, September 12-14, 1958, under the direction of Prof Mituharu Goto, M D , Otorhinolaryngological Clinic, Kyoto University Hospital, Kyoto, Japan

A registration fee of $25 00 U S A. will be charged all physicians and a fee of $10 00 for wives or non-medical guests Registered members are admitted free to banquet, receptions and sightseeing tours

FOUR UNUSUAL CASES OF TEMPORAL BONE DISEASE *

DAVID D DEWEESE, M D ,

Portland, Ore

Review of the recent otolaryngologic literature reveals only one case report of infection of the petrous portion of the temporal bone Lest we forget that this condition still occurs, I am presenting three cases, which I believe, emphasize the principal symptoms produced by disease in this region

The fourth case is not one of temporal bone infection, nevertheless, it is presented because not only the area involved but also the circumstances of the involvement are unusual

CASE REPORTS

Case 1 A man aged 63 was first seen on June 2 1954, because of discharge from the right ear double vision, and dizziness

Symptoms began seventeen days prior to admission First, he had pain in the right ear Several hours later there was a bloody discharge from the ear He was hospitalized and given terramycin and penicillin intramuscularly This relieved the pain but the ear continued to drain Twelve days prior to admission he became aware of double vision and of dizziness There was no other contributory history

Examination of the nose, throat, nasopharynx, larynx and left ear was normal The right ear showed a pulsating, purulent discharge from a central perforation of the eardrum The eardrum was thick and pink but not bulging The mastoid was tender

On general physical examination the patient was well oriented He had complete lateral rectus paralysis in the right eye There was partial paralysis of the VIIth nerve of a peripheral type There was nystagmus to the left The neck was not stiff Temperature was 99 5 degrees

Leukocyte count was 11 500 Roentgenogram of the mastoid showed some sclerosis with definite decalcification of the intercell walls, in addition, there was erosion of the inner table of the petrous ridge on the right side Chest roentgenogram was normal

He was hospitalized and given heavy doses of penicillin The following day a radical mastoidectomy and petrous exploration were done The mastoid portion of the temporal bone was the seat of active subacute purulent infection with cell destruction There was no erosion of the

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*Read at the meeting of the Western Section American Laryngological Rhinological and Otological Society Inc Beverly Hills Calif Jan 18 1958

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labyrinth Healing granulations were present over one area of the sigmoid sinus Posterior to the labyrinth there was a tract of cells A similar tract of cells was present inferior to the labyrinth It was possible to enter the body of the petrous superior to the labyrinth In this area there was inflammatory tissue and soft bone, but no frank pus

Postoperative recovery was somewhat slower than is usual after radical mastoidectomy but except for slight fever in the afternoon he was up oriented eating, and appeared well On June 13 (ten days postoperatively) he suddenly became semi-comatose then comatose Fever rose to 103 degrees There were no localizing signs

A neurosurgical consultant followed him for four days On the fourth day flaccid paralysis appeared in the left arm and left leg Babinski was positive. The neck was stiff but not rigid There was no papill edema. Leukocyte count was normal Spinal fluid showed a mild increase in protein and 75 cells all of which were lymphocytes

In view of these findings the patient was taken to the operating room for the second time (June 17) The old mastoid incision was reopened after which the petrous was again examined A wide examination was also made of the dura of the middle as well as the posterior cranial fossa The dura was normal Under the same anesthetic a neurosurgeon opened the right temporal area and probed the temporal lobe to see if there was an abscess None was found

Patient s condition following operation remained poor 48 hours later he expired

Autopsy showed a healing mastoid petrous wound There was no evidence of brain abscess Three areas of malignant metastases were found one over the midline of the dura on the left side the second deep in the cerebellum near the dentate nucleus and the third in the left side near the surface of the temporal cortex Both adrenal glands were filled with metastatic carcinoma There was no evidence of malignancy in the mastoid or the petrous The primary lesion was presumably a small carcinoma in the medial portion of the left lung lying immediately behind the heart. Recheck of the chest roentgenogram taken preoperatively failed to reveal the lesion

Case 2 A woman aged 33 was first seen on January 26 1956 because of persistent headache on the right side discharge from the right ear and low grade fever

She stated she had had draining from the right ear since she was 18 months old Eleven years prior to admission after swimming the ear became painful and the discharge increased A diagnosis of acute mastoiditis was made and a partial mastoidectomy (whatever that is) was performed Following this operation the ear continued to drain and she had intermittent pain in the ear

Three years prior to admission she began to have a low grade fever and the discomfort in the ear increased A radical mastoidectomy was performed at that time The ear healed Occasionally she had discharge from the ear for periods of 24 or 48 hours but without pain

One month prior to admission she had severe headache on the right side and nausea This was followed by increased discharge from the ear without pain Ten days prior to admission she had difficulty in focusing the eyes and there was some blurring of vision The headache also recurred and she had a low grade fever of between 99 and 100 degrees She stated that when she was quiet she was fairly comfortable but when she was sitting up or walking the headache was severe She was unable to read print except for a few minutes She denied double

vision Leaning or turning to the left produced nausea without vomiting In addition to the headache she had a pain which she described as deep aching behind the right eye

On examination the throat, nose, and left ear were normal The right ear showed a clean radical mastoid cavity, in which all structures were visible The round window, the oval window with the stapes bound down, and the intratympanic course of the facial nerve were clearly visible There was some moisture in the region of the Eustachian tube There was a small area of exposed bone behind the labyrinth Suctioning of the middle ear area produced slight dizziness and nystagmus The fistula test was negative

Blood count was normal Roentgenograms showed the previous surgical defect. In the apex of the petrous the cells were clouded without definite bone destruction

Neurologic examination was entirely normal except that the neurologist felt the history indicated definite meningeal irritation An electroencephalogram was reported as abnormal because of isolated slow waves which arose in both hemispheres, but more so on the right Extraocular muscle function, visual fields, and fundi were normal

A diagnosis of petrositis was made, and operation was advised

Exploration of the right temporal bone was done on January 30, 1956 The previously described mastoid cavity was clean, except for pus in one tract of cells immediately superior to the intratympanic course of the facial nerve and in another tract of cells behind the labyrinth Exploration of the postlabyrinthine tract failed to reveal anything unusual There was a wide space of pneumatization superior to the superior semicircular canal making it possible to explore the petrous deeply under direct vision The bone of the body of the petrous was granular and soft There was granulation tissue in most of the body of the petrous to the apex This was removed

After operation the headache disappeared Visual disturbance also disappeared She was discharged eight days postoperatively Except that the cavity was slow healing she did well for six weeks and then symptoms recurred Over the next three months she had intermittent headache and intermittent blurring of vision Then all symptoms subsided

Ten months postoperatively she began to have fever, which slowly increased to 102 degrees There was also recurrence of retro ocular pain In addition she had some chilly sensation but no real shaking chills Examination at this time showed the ear to be moist All other studies, including neurologic examination were within normal limits

She was carefully followed for one month During this period the temperature ranged from 99 5 to 102 degrees The only complaints otherwise were a feeling "as though I were being pulled over backwards" and increasing drowsiness

Because of the fever and other symptoms as well as the persistent discharge the temporal bone was again explored on November 23 1956, 11 months after the first exploration In the angle between the superior semicircular canal and the middle fossa dura a piece of sequestrated bone was found The petrous body and apex were again filled with soft granular bone which had the appearance of proliferative osteomyelitis This was removed The inner table of the roof of the petrous was removed toward the tip until solid bone was encountered in all directions Although the nerve could not be identified the internal auditory meatus must have been approached since there was twitching of the face Fur

ther removal of bone was discontinued A small polyethelene tube was placed in the petrous tip, and brought out into the mastoid cavity

The tube was slowly removed over a period of six weeks Penicillin and chloromycetin were used continuously throughout hospitalization and for six weeks after discharge The ear healed primarily Since that time the patient has been clinically well and symptom free

Case 8 A man aged 49 was first seen on June 28 1955 His chief complaint was progressive hearing impairment in both ears of three years duration

He stated that during examination in 1952 his attention was called to the fact that the right side of his face appeared to be weak There was, however no paralysis He gave no history of tinnitus or dizziness

Examination of the nose throat nasopharynx and larynx was normal The palate rose normally The tongue and vocal cords moved normally There was weakness of all branches of the VIIth nerve on the right side The corneal reflexes were normal The left ear was entirely normal The right eardrum was intact. *Through the eardrum* a small white area was visible anterior to the short process of the malleus

The audiogram was normal up to 2 000 cycles per second There was a high tone loss of hearing in both ears somewhat worse on the *left* side

Roentgenograms of the mastoid the skull and the internal auditory meatuses were normal Electrical tests of the right facial nerve showed equal chronaxie on both sides but elevation of the voltage required and of rheobase on the right side

A presumptive diagnosis of neuroma of the facial nerve was made and exploration advised The patient returned to his original physician who advised strongly against any type of operation on the ear

Seven months later on February 7 1956 he came back for re-examination In this interval his face had gradually become more paralyzed His eye was tearing He had had some paresthesias of the right side of the tongue and one or two momentary spells of true vertigo

Examination showed a definite small white mass which was pushing Shrapnel s membrane out in front of the malleus Electrical testing of the right VIIth nerve gave results identical with those obtained by testing seven months previously A complete neurologic examination was otherwise normal

This time the patient accepted advice for surgical exploration but operation was not performed until June 6 1956 The mastoid was normal and well pneumatized The antrum was normal After removal of the bony bridge over the aditus it became evident that the attic was full of a mass which appeared to be cholesteatoma The incus and head of the malleus were removed The horizontal semicircular canal was prominent There was no evidence of a superior semicircular canal The normal position of the superior semicircular canal was occupied by a large cholesteatoma which filled the medial part of the attic It extended underneath the intratympanic portion of the facial nerve as well as over the labyrinth and on top of the body of the petrous An area of the inner table was eroded and the dura was exposed for an area one-and a half cm in diameter in the floor of the middle fossa medial to the labyrinth The intratympanic course of the facial nerve had been completely exposed by the cholesteatoma All of the cholesteatoma was removed and the facial nerve was decompressed to the stylomastoid foramen

The pathologic report confirmed the clinical diagnosis of cholesteatoma

Postoperatively the radical mastoid cavity healed normally Because of

vision Leaning or turning to the left produced nausea without vomiting In addition to the headache she had a pain which she described as deep aching behind the right eye

On examination, the throat, nose, and left ear were normal The right ear showed a clean radical mastoid cavity, in which all structures were visible The round window, the oval window with the stapes bound down, and the intratympanic course of the facial nerve were clearly visible There was some moisture in the region of the Eustachian tube There was a small area of exposed bone behind the labyrinth Suctioning of the middle ear area produced slight dizziness and nystagmus The fistula test was negative

Blood count was normal Roentgenograms showed the previous surgical defect. In the apex of the petrous the cells were clouded without definite bone destruction

Neurologic examination was entirely normal except that the neurologist felt the history indicated definite meningeal irritation An electroencephalogram was reported as abnormal because of isolated slow waves which arose in both hemispheres, but more so on the right Extraocular muscle function visual fields, and fundi were normal

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Case 3 A man aged 49 was first seen on June 28 1955 His chief complaint was progressive hearing impairment in both ears, of three years duration

He stated that during examination in 1952 his attention was called to the fact that the right side of his face appeared to be weak There was however no paralysis He gave no history of tinnitus or dizziness

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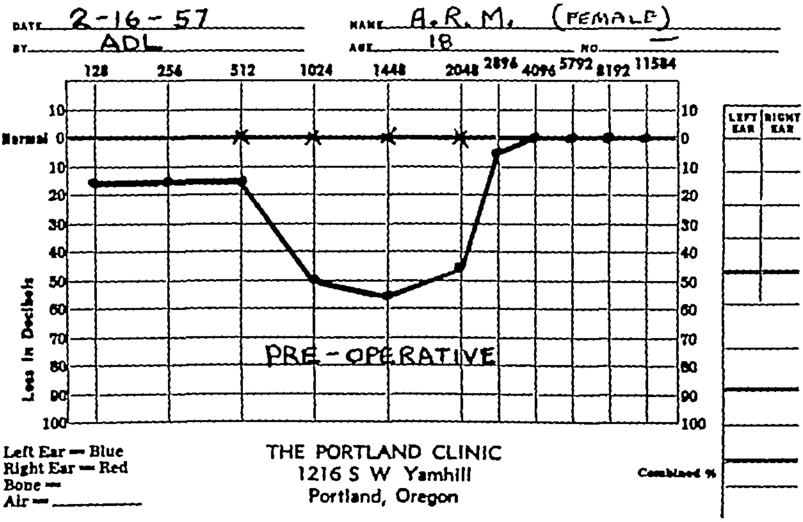
The patient was not seen again until June 21, 1957 approximately one year after operation Examination showed definite motion of all branches of the right facial nerve except the frontalis The patient said he had noticed beginning motion in March of 1957 He also said that on occasions he had had a momentary feeling of propulsion, but no real vertigo

Audiograms at this time showed 50 decibels loss of hearing up to 1 500 cycles per second There was a sharp drop above that to 100 db loss at 6,000 cycles per second



DATE 2-16-57
BY ADL
NAME A.R.M. (FEMALE)
AGE 18
NO. —

Case 4 A girl, aged 18 was examined on February 16, 1957, because of hearing loss and low pitched buzzing tinnitus

Seven months prior to admission on July 21, 1956 she had been the guest passenger in the front seat of a car An accident occurred during which she was thrown forward and hit the left side of her head against the dashboard There was no facial laceration or unconsciousness The left ear bled some, but it was not treated

She noted loss of hearing in the left ear immediately after the accident, and for one week after the accident she had a loud buzzing tinnitus This improved somewhat but a low pitched buzzing tinnitus persisted There had been no vertigo at any time She denied past ear disease, and claimed entirely normal hearing prior to the accident, however, she had never had the hearing tested

Examination disclosed no abnormalities except for the left ear The eardrum on this side appeared to be slightly retracted The incudostapedial joint was visible through the drum and appeared to be in normal position The above audiogram of the left ear showed

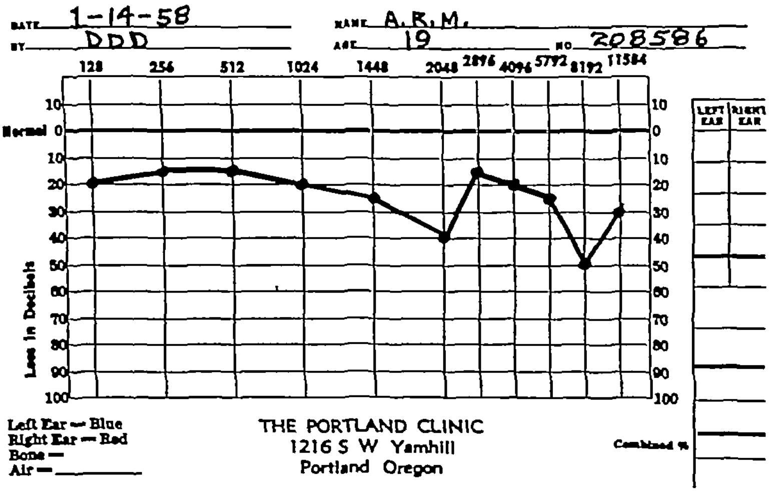
This is a pure conductive hearing loss Inflation of the Eustachian

tube on the left side produced only a 10 decibel improvement at 1 500 cycles and a 5 db improvement at 2 000 cycles With both 500 and 1 000 cycle tuning forks the Weber test was constantly lateralized to the left ear even when the right external auditory canal was occluded The Rinné test was negative on the left side with both forks These tests had been done previously by two other otolaryngologists

Roentgenograms of the mastoid showed normal well areated temporal bones on both sides

A diagnosis of probable dislocation of the incus was made

On March 27 1957 eight months after the injury exploratory operation was performed Since it was anticipated that the incus might have to be removed the middle ear was approached through the postaural incision Enough mastoid cells were removed to permit easy visualization of the middle ear There was a large zygomatic extension of air cells which made it possible to expose the attic of the middle ear without disturbing the soft tissue of the external auditory canal or the eardrum



DATE 1-14-58
NAME A.R.M.
BY DDD
AGE 19
NO 208586

Careful removal of the inner quarter of the bony external canal down to the *horizontal* semicircular canal allowed visualization of the ossicles The incudo-malleolar joint appeared to be normal The superior malleolar ligament was normal The incus was completely dislocated from the stapes Directed anteriorly it was holding the stapes partially fixed however there was some mobility of the stapes Since it was not possible to replace the incus on the head of the stapes so that it would remain it was therefore removed The cavity was closed

The above audiogram of the left ear taken on January 14 1958 ten months postoperatively, showed

The result is best stated in the patient s words 'I hear 100 per cent better and I notice it mostly in conversation '

Although the final hearing result is not normal it falls in the range of better than 25 db in all speech tones except those of 2 000 cycles per the facial paralysis which became complete, electrical treatments were carried out daily Two and a half months postoperatively slight motion of the nasalus muscle was suspected This was more definite by the end of four and a half months

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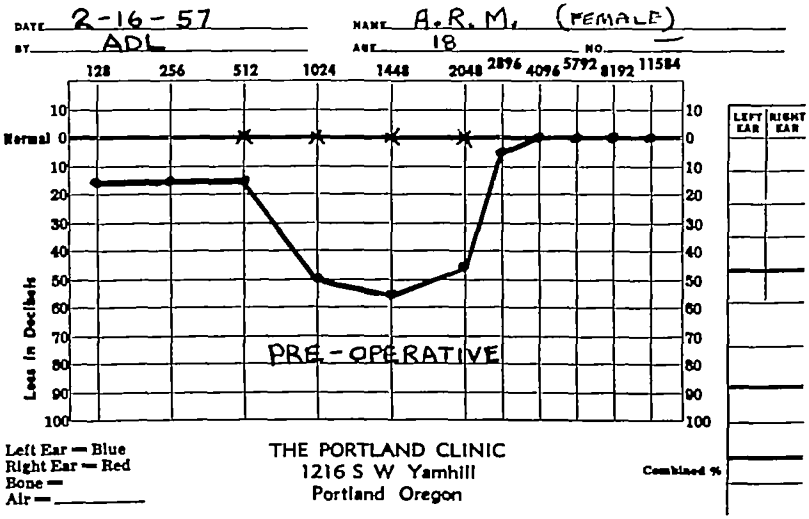

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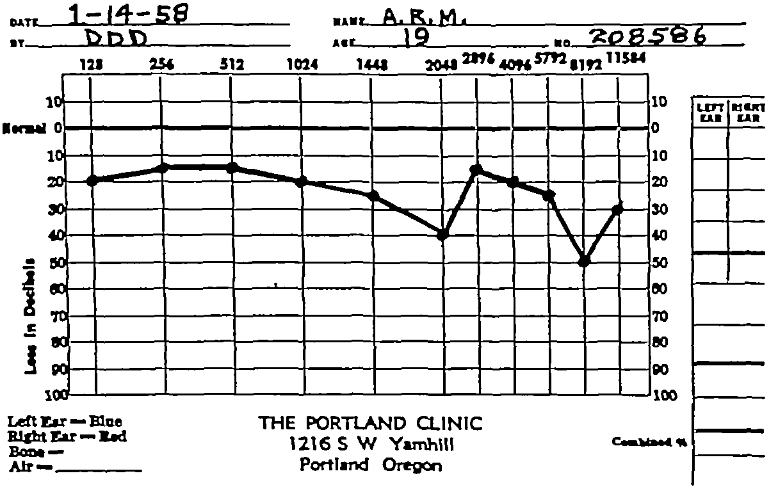

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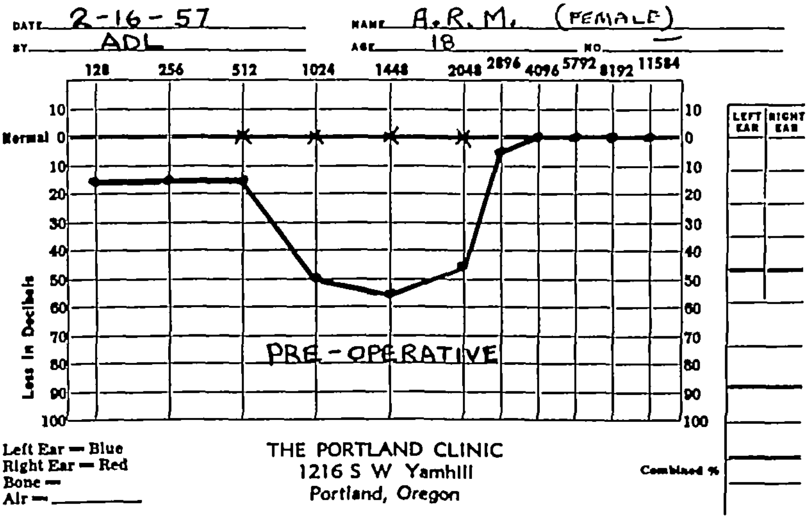

DATE 2-16-57
BY ADL
NAME A.R.M. (FEMALE)
AGE 18
NO. —

THE PORTLAND CLINIC
1216 S W Yamhill
Portland, Oregon

Case 5 A girl, aged 18 was examined on February 16 1957 because of hearing loss and low pitched buzzing tinnitus

Seven months prior to admission on July 21, 1956, she had been the guest passenger in the front seat of a car An accident occurred, during which she was thrown forward and hit the left side of her head against the dashboard There was no facial laceration or unconsciousness The left ear bled some, but it was not treated

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BIBLIOGRAPHY

1 DAY, KENNETH M A Primary Cholesteatoma of the Middle Ear Case Report *Ann Otol, Rhinol and Laryngol*, 64 161-163 March, 1955

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INSTITUTE ON INDUSTRIAL DEAFNESS

Colby College, Waterville, Maine, presents the Sixth Annual Institute on Industrial Deafness, August 11-20 inclusive Please note that the course has been extended for three days in order to include engineering for noise control Its objective will be to train physicians interested in the problem, nurses, plant engineers and others in initiating and conducting hearing conservation programs in noisy industries The course includes basic otology, audiometry, noise measurement, ear protection and methods of noise control Class is limited to approximately twenty participants

The fee for the course is $250 and includes tuition, room and board The first week will constitute a complete course for doctors and nurses, and the reduced fee for this will be $200 Application should be made to Mr William A. Macomber, Colby College, Waterville, Maine second These findings would tend to confirm the stated opinion of others that serviceable hearing is possible without the ossicular chain They also support the feeling that an intact ossicular chain is responsible for 20 to 25 decibels of hearing

Speech reception threshold was recorded at 26 28 decibels Tolerance to loud sound was normal Ninety decibels of sound, pure tone, and white noise were not uncomfortable

COMMENT

The variation in the histories of the first three patients emphasizes the different symptoms and signs which can be produced by disease of the petrous portion of the temporal bone These are annoying recurrent pain, usually behind the eye, persistent aural discharge, paralysis of the VIth and VIIth nerves, meningeal irritation, vertigo

The first patient had all symptoms and signs except retro-ocular pain The second had all signs except VIth and VIIth nerve paralysis, but there were signs of ease of ocular muscle fatigue The third patient showed only VIIth nerve paralysis and mild, nondiagnostic vertigo

Roentgenograms of the petrous (Stenver's and base plates) gave valuable information in two of the patients These are necessary additions to routine mastoid films when any deep involvement is suspected

The case of primary cholesteatoma is interesting because it is rare As in a similar case, reported by Dr Kenneth Day,[1] the mastoid portion of the temporal bone was normally pneumatized

Exploration and drainage of pus or removal of diseased bone is essential to successful recovery when the petrous is involved It is, therefore, evident that the otolaryngologist must constantly review the anatomy of the deep temporal bone Antibiotics alone are not the answer

SUMMARY

Three cases of disease of the petrous portion of the temporal bone are presented Despite the rarity of petrositis, it points up the necessity of constant review of the anatomy of the deep temporal bone

One case of dislocation of the incus is also reported Surgical removal of this bone was followed by clinically useful hearing

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INSTITUTE ON INDUSTRIAL DEAFNESS

Colby College, Waterville, Maine, presents the Sixth Annual Institute on Industrial Deafness, August 11-20 inclusive Please note that the course has been extended for three days in order to include engineering for noise control Its objective will be to train physicians interested in the problem, nurses, plant engineers and others in initiating and conducting hearing conservation programs in noisy industries The course includes basic otology, audiometry, noise measurement, ear protection and methods of noise control Class is limited to approximately twenty participants

The fee for the course is $250 and includes tuition, room and board The first week will constitute a complete course for doctors and nurses, and the reduced fee for this will be $200 Application should be made to Mr William A Macomber, Colby College, Waterville, Maine

EXPERIMENTAL OBSERVATIONS ON SQUAMOUS METAPLASIA OF THE TRACHEA *†

NOBLE O CORRELL, M D ,
and
EDWARD J BEATTIE, JR , M D ,
(By Invitation),
Chicago, Ill

INTRODUCTION

In 1955 we began studies of the physiology of the trachea[1] Since much of the research on respiratory epithelium has been accomplished by otolaryngologists we felt that our findings might be of interest to this group

REVIEW OF THE LITERATURE

More than 25 years ago there had been numerous observations on the physiology of the epithelium of the respiratory passages, by several different investigators[3,4,9,10,11]

In 1956, Hilding published a series of four articles on cigarette smoking, bronchial carcinoma and ciliary action[5,6,7,8] Proetz has also made numerous substantial contributions to the understanding of the physiology of respiratory epithelium[12,13] A complete review of the above literature in this paper is not possible nor necessary

We were interested in knowing whether the direction of beat of the cilia was inherent within the cell or due to some other factor We also wanted to know whether an autogenous devascularized free tracheal graft would survive, and if so, how the epithelium regenerated

In both dogs and chickens it was possible to excise two-

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*Read at the meeting of the Middle Section of the American Laryngological Rhinological and Otological Society Inc Chicago Ill Jan 13 1958

†From the Surgical Research Laboratories Presbyterian-St. Luke's Hospital and the University of Illinois School of Medicine Chicago Ill

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inch segments of the cervical trachea and anastomose the devascularized autogenous tracheal segment in a reversed direction, so that the cilia of the graft pointed caudad Those animals and birds which survived were killed and autopsied after variable periods The trachea, including the graft, was excised, fixed and stained for histological examination

The graft showed ischemic degenerative changes throughout the first 12 days During this period the only remnant of the epithelium was islands of reserve cells which were always in evidence Approximately two weeks following the reversal of the graft, revascularization could be seen in the sub-mucosal stroma, and by three weeks the normal ciliated epithelium had completely regenerated from the surviving islands of cuboidal type reserve cells

It was demonstrated that the cilia of the reversed tracheal graft retain their direction of beat with respect to the graft, thus propelling the overlying mucus stream caudad

An incidental finding during these experiments was that in the dog, the circumferential tracheal anastomoses tended to stricture Such a tendency could be discouraged by rotating the graft so that the membranous portions of the graft and trachea did not meet This purposeful rotational mal-alignment resulted in a ring of solid cartilage at the anastomotic sites which resisted stenosis

The chickens, having complete cartilaginous rings without a membranous portion, showed no tendency toward stricture of their tracheal anastomoses

Another incidental finding was that the birds and animals with reversed tracheal grafts always carried a ring of mucus at the caudad anastomosis, where it was continuously being piled up by the cilia These creatures were forced to cough at regular intervals to clear their mucus accumulations

The proximal anastomosis was always dry and underwent squamous metaplasia When the anastomoses were excised and the ends re-approximated, squamous metaplasia again occurred at the site of the proximal anastomosis This find-

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ing was present in all of the birds and animals with reversed tracheal grafts

The work just described has been previously reported[1,2]

METHODS

Four dogs were allowed to live longer than one year after their tracheal graft reversals Two dogs were killed on their

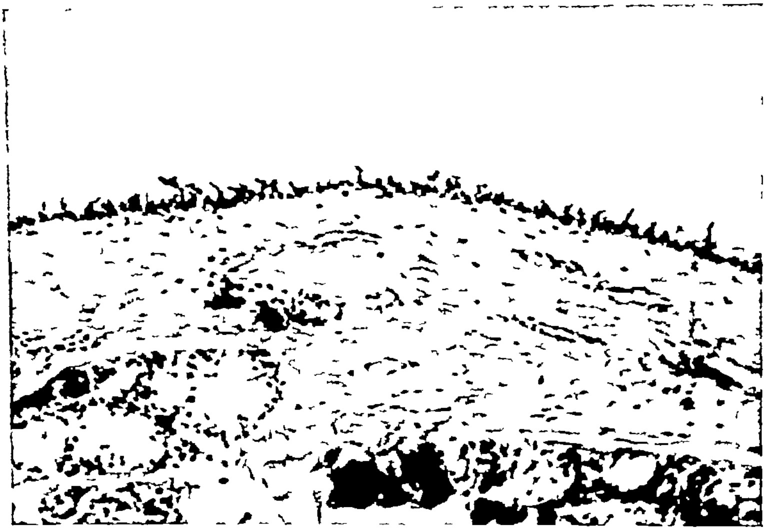

Fig 3 Trachea caudad to reversed graft in a dog 500 days after reversal of cervical trachea and nine days after permanent tracheostomy cephalad to the graft Note the absence of ciliated columnar cells which have presumably sloughed as the result of inflammation from retained secretions

400th post-operative day They were autopsied and their tracheal grafts, including the anastomoses, were prepared for histological examination Two dogs were given permanent tracheostomies, bringing the cricoid cartilage out as a tracheal stoma on their 450th and 500th post reversal day respectively

A fifth dog is living as a pet, with a cervical trachea reversed more than two and one-half years ago

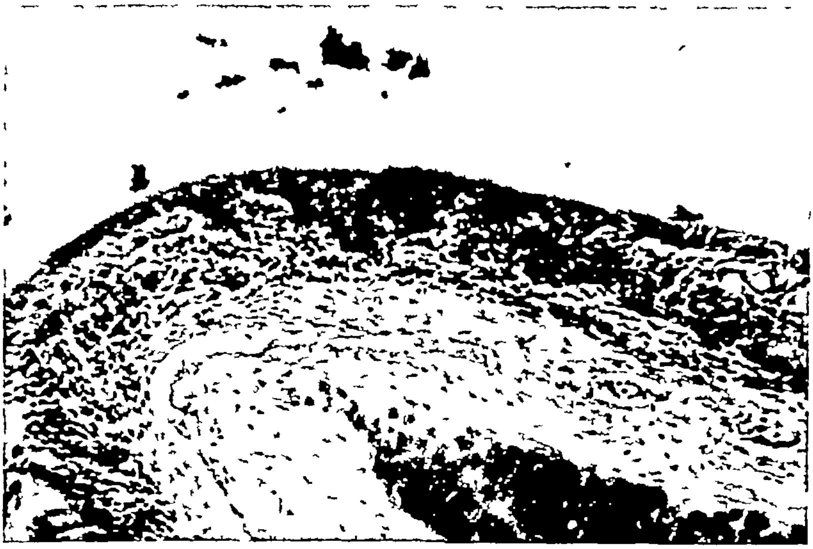

Fig 1. Squamous metaplasia of proximal anastomosis of reversed autogenous tracheal graft

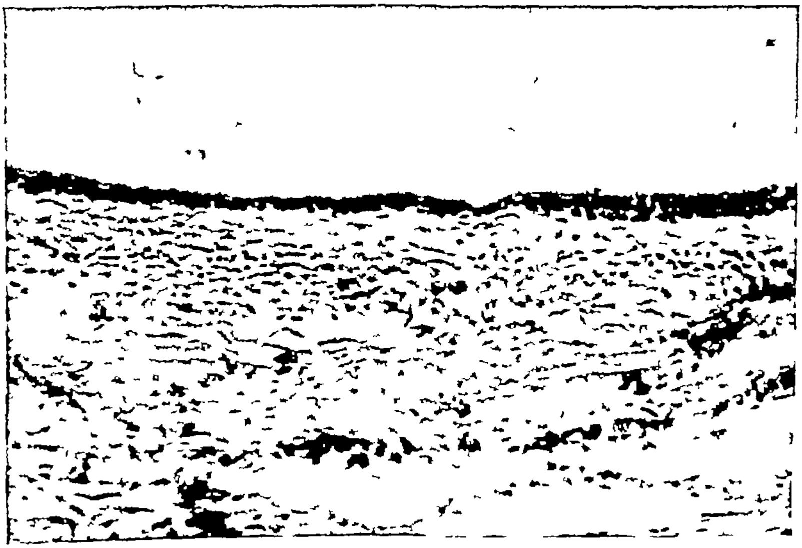

Fig 2 Persistent squamous metaplasia of proximal anastomosis 400 days after reversal of cervical trachea in the dog

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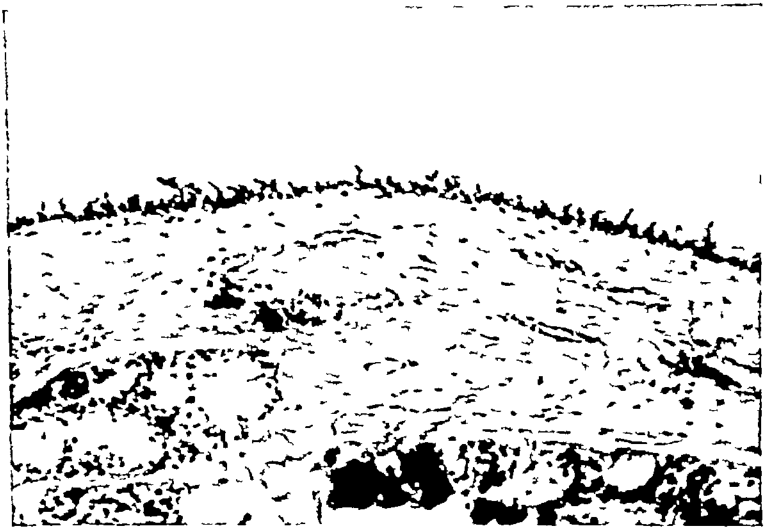

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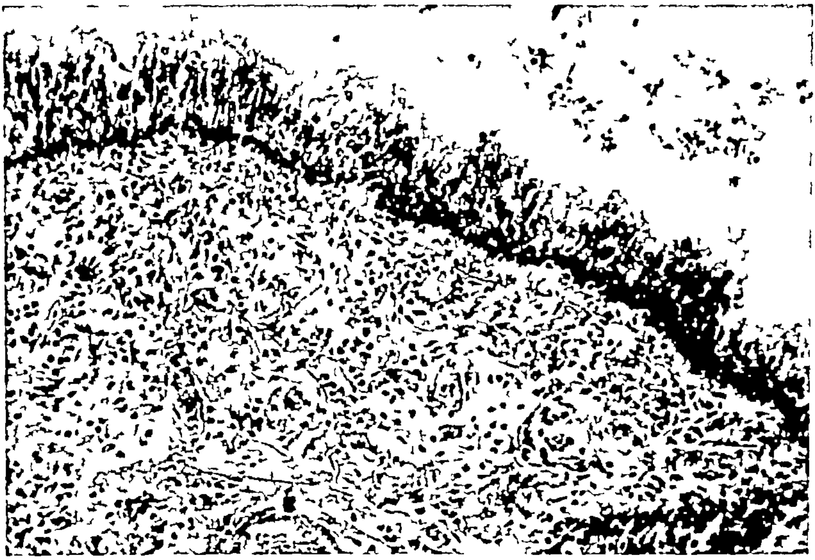

Fig 4 The reversed graft of the same animal depicted in Fig 3 Note the marked vascularity and inflammatory cells beneath the mucosa

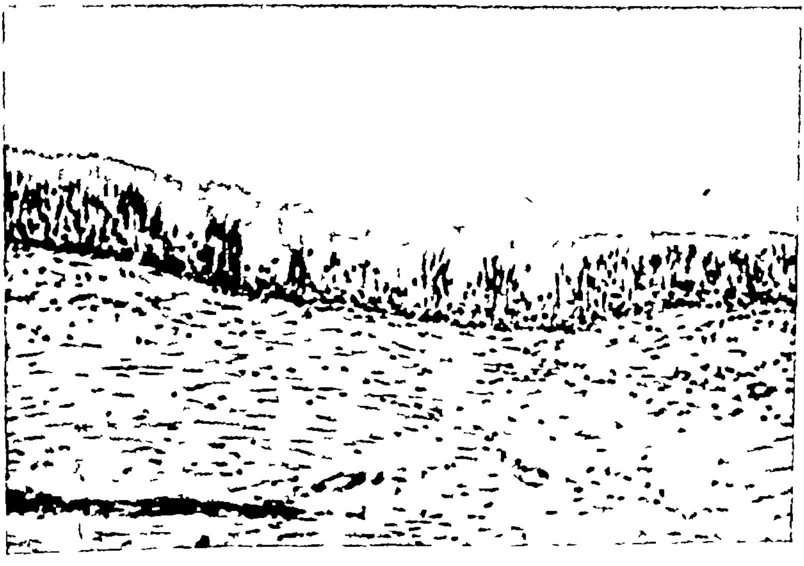

Fig 5 A tracheal graft in the dog four months following reversal showing a large number of mucus producing cells in the regenerated epithelium

RESULTS

The two dogs killed 400 days following reversal of their cervical tracheas showed heavily ciliated columnar epithelium lining the graft There was squamous metaplasia of the proximal anastomosis which differed in no respect from the metaplastic changes found in the proximal anastomoses of all the previous specimens examined (see Figs 1, 2)

The two dogs given permanent tracheostomies died eight and nine days later of retained secretions, with asphyxia and severe tracheo-bronchitis The epithelium of their tracheas differed from that of their grafts, in that the trachea showed uniform survival of the reserve cells only, in an orderly solid sheet (see Fig 3), while the grafts showed more sub-mucosal vascularity and a thicker, more metaplastic and basophilic epithelium (see Fig 4)

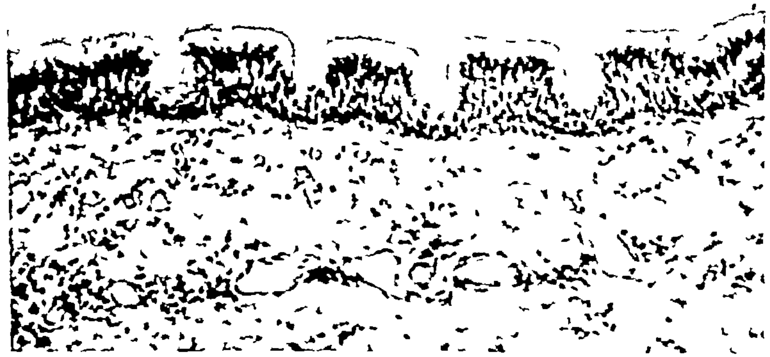

Fig 6 Another section from the same graft as Fig 5 showing mucus pits

DISCUSSION

Whether this heavier, better preserved epithelium is the result of a better blood supply or a distorted growth pattern brought about by the previous phase of regeneration of the graft is not known

It does appear that the epithelium of the graft usually differs in some respects from the normal respiratory epithelium There are more mucus producing cells in the epithelium of the grafts (see Fig 5), and many of these cells are clumped together, forming a cluster of ciliated goblet cells located around a depression in the surface of the mucosa (see Fig 6) These glandular, mucus producing pits, lined by cilia, are more numerous than the well-known racemose glands of the tracheo-bronchial tree The "mucus pits" are also more shallow, the entire glandular aggregate being superficial to the basal layer of reserve cells of the epithelium

Even the surface of normal tracheal epithelium is pockmarked by glandular orifices when examined under suitable magnification and illumination Whether these craters represent "mucus pit" glands or openings of the racemose glands ducts is not known

SUMMARY AND CONCLUSIONS

1 Squamous metaplasia of the cephalad anastomosis of reversed autologous tracheal grafts persists for more than one year

2 The mucosal lining of the grafts seems unusually well supplied with ciliated goblet cells, frequently clustered around "mucus pits"

3 The regenerated epithelium of the grafts exhibits an abnormal response to infection, the significance of which is unknown

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UNUSUAL TUMORS OF THE TONSIL AREA *†

LEWIS W JORDAN, M D ,

Portland, Ore

INTRODUCTION

Since disturbances of the tonsil and its surrounding structures are commonly caused by infection, it was thought that by way of contrast a discussion of five tumors in this area would be of general interest and value

These tumors are *1* Osteoma of the inner surface of the mandible presenting in the left tonsil fossa, *2* Fibro-liposarcoma arising on the dorsum of the tongue and extending into the right tonsil fossa, *3* Mixed tumor of aberrant salivary gland in the nasopharynx invading the left posterior pillar, *4* Malignant lymphoma of the right tonsil, *5* Squamous cell carcinoma of the left tonsil The first three tumors occur rather commonly in many parts of the body but are unusual in the sites to be described, while the last two neoplasms are occasionally seen only in the tonsils

OSTEOMA OF MANDIBLE

Case 1 Mrs V H white, age 50 was referred on Nov 29, 1954 because of an asymptomatic medial protrusion of the left tonsil which had been found during a routine physical examination The tonsils were atrophic and the one on the left appeared to be displaced medially by a large firm, discrete, and fixed mass about 5 or 6 cm in diameter coming up from the base of the tonsil fossa The ear, nose, throat nasopharynx, larynx, sinuses, and neck showed no essential pathology, and the general examination was not contributary The report of a small biopsy was "chronic tonsillitis with focal ulceration"

Under general anesthesia on Dec 13, 1954, a vertical incision made behind the anterior pillar immediately disclosed a smooth and spherical osteoma with the atrophic tonsil stretched over it Both tonsils were *removed by dissection and snare The bony tumor was found to be at*tached to the inner surface of the angle of the mandible by a very broad base By means of mastoid gouges several large fragments of the mass were removed The bone was so hard that the edge of one gouge was

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†From the Department of Otolaryngology University of Oregon Medical School Portland Ore

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broken By this time it was evident that complete removal of this benign tumor would be a major procedure which was not justified by the symptoms Accordingly the wound was closed by suturing the anterior and posterior pillars together

The pathology report by Dr Warren C Hunter was as follows In addition to tonsils there are a number of pieces of bone the largest measuring 2 5x1 5 cm having roughened and somewhat cancellous surface opposite to a smooth and convex aspect The mass cut with great difficulty and mostly appeared solid rather than cancellous

In microsections the mass proved to be extremely dense bone poor in bone cells and with a good many Haversian canals present. If this is other than an exostosis it can be termed an osteoma (see Fig 1)

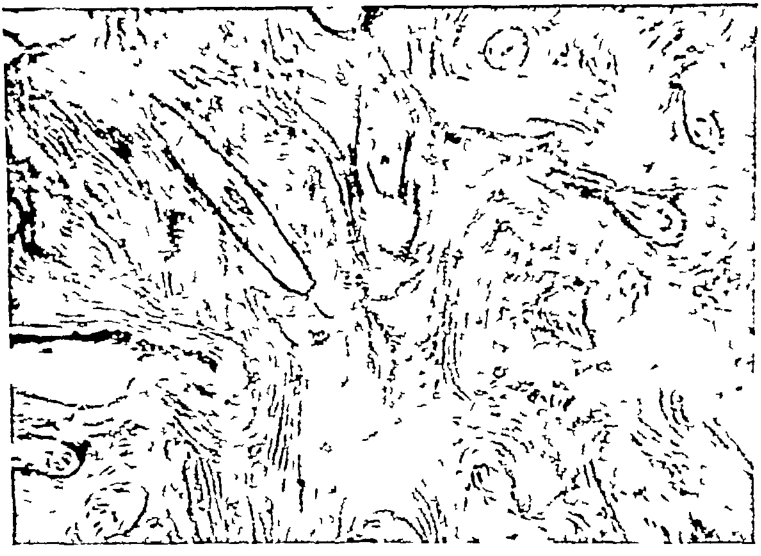


Fig 1 Case 1 Photomicrograph (X160) depicting representative structure of osteoma together with Haversian canals

By Dec 20 the edges of the wound had separated and the bare osteoma was widely exposed On Jan 21 1955 the bony mass was still completely exposed with no evidence of progress in covering by soft tissue however shortly thereafter a large superficial sequestrum was removed which revealed healthy granulations extending over the entire osteoma In a few days the area was completely covered by normal mucosa

The post-operative X ray report of Dr Arthur L Hunter on Dec 23 1954 stated Radiography of the left mandible shows a huge semi-oval calcium density projecting medial to the angle of the mandible on the left side This density measures about 5 or 6 cm in greatest diameter and has the radiographic characteristics of a huge osteoma (see Fig 2)

The patient was last seen on Aug 20 1957 at which time the mass appeared to be unchanged in size and the patient was having no throat symptoms

Thoma[1] described the removal of a similar tumor by an extraoral approach The mass was so large that it interfered with talking and prevented the wearing of an upper denture Because the osteoma was so hard it was necessary to remove part of the cortex of the mandible with the specimen The same writer states,[2] "The development (of an osteoma) may occur in any part of the maxilla and mandible and arises from preformed bone, periosteum or retained cartilage cells from the embryonic chondroskeleton Growth is progressive, but slow, and the tumor is benign in character It starts spontaneously and is believed by many to be of traumatic but noninflammatory origin Its growth generally ceases with the termination of general skeletal development"

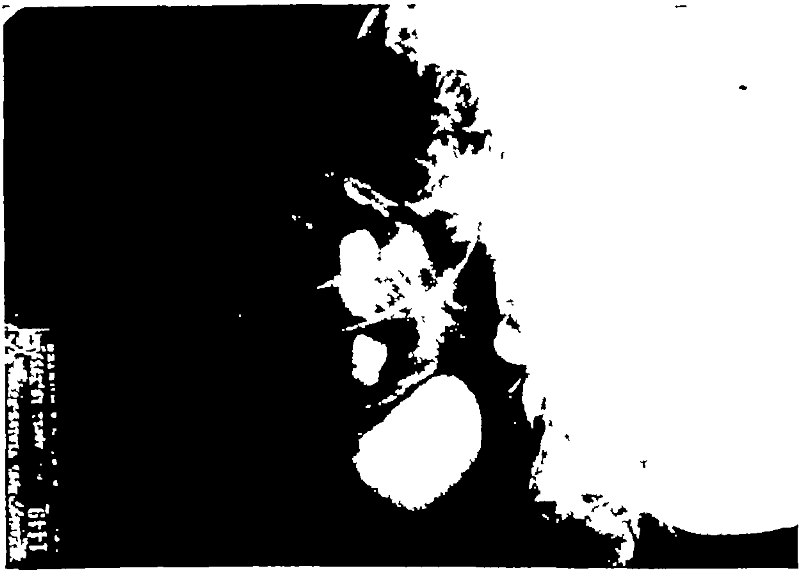


Fig 2 Case 1 Osteoma of Mandible as seen by X-ray

Uhler[3] presented the case of a man with such a large pedunculated osteoma attached to the lower first molar area that the tongue was displaced, making the intake of food difficult The tumor was thought to be the result of a blow to the lower jaw 37 years before Removal was accomplished with a Gigli saw

Rosedale and Hargraves[4] reported the case of a colored man with an osteoma of the inner surface of the mandible extending from the left lateral incisor tooth as far posteriorly as the posterior pillar of the tonsil and extending vertically from the superior surface of the mandible to the inferior surface Because of difficulty in swallowing and speaking it was removed intraorally

True osteomas occur rather frequently in the frontal sinus Ewing[5] states that these arise from fragments of cartilage connected with the ethmoid Osseous change of the maxilla and mandible often is associated with dental pathology and the occurrence of an exostosis is rather common At times, bone is combined with cartilaginous, fibrous, or other types of tissue in a neoplasm The torus palatinus and torus mandibularis are common and usually cause difficulty only in the wearing of dentures

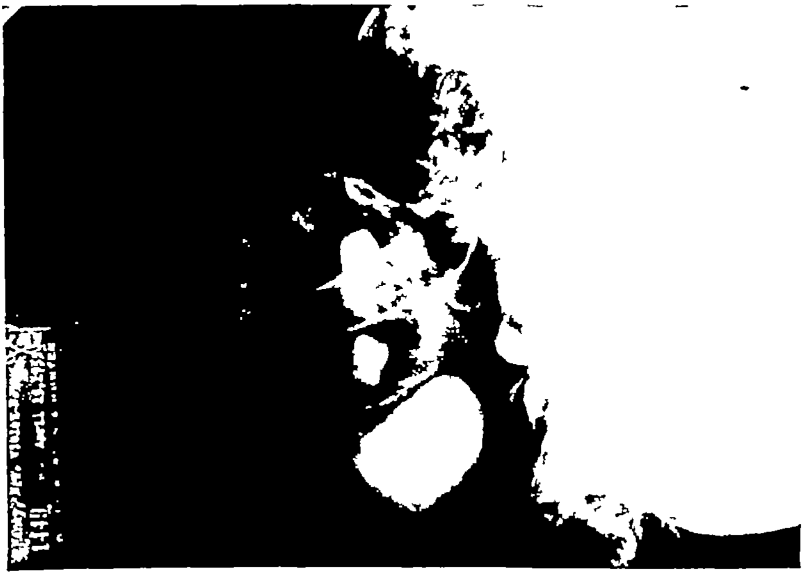
FIBRO-LIPOSARCOMA OF THE TONGUE

Case 2 Mr M R white, age 45 sought treatment on Nov 4 1944 because of the sensation of a foreign body in his throat. He stated that in 1923 (age 24 yrs) a tumor had been removed from the posterior part of his tongue The record of this procedure was not available Later he was treated by the late Dr Frank B Kistner of Portland Ore whose record was as follows This patient was seen in 1927 (age 28 yrs) at which time a large mass was found attached to the lower outer border of the anterior surface of the right side of the epiglottis On Jan 7 this was removed by sharp dissection under suspension laryngoscopy The pathological diagnosis was adenomyxoma with doubtful malignancy In May 1941 a biopsy was taken which showed no malignancy

The examination in 1944 (age 45 yrs) showed a rather large yellow smooth soft and lobulated mass on the right side of the tongue extending from the epiglottis to the deep surface of the right tonsil (see Fig. 3) Nothing else of significance was found in the local or general physical examination On Dec 7 1944 under general anesthesia the tumor was removed by sharp dissection along with both tonsils The tumor had extended between the capsule of the right tonsil and the fossa bed Bleeding was slight and the mass whose dimensions were 4 5x3 5x1 cm was surrounded by a definite capsule and was on the surface of the tongue The pathological diagnosis by Dr Warren C Hunter was submucous lipoma He commented that this was the first time that he had seen a lipoma in this location

The wound healed well and periodic examinations showed no recurrence until June 20 1952 (age 53 yrs) when a discrete mass about 1 cm in diameter with a broad base was found on the right side of the tongue in the vallecular fossa The patient returned for surgery on Feb 7 1953 The tumor was now about the size of an olive and was removed by sharp dissection under local anesthesia A small adjoining mass was also resected

Thoma[1] described the removal of a similar tumor by an extraoral approach The mass was so large that it interfered with talking and prevented the wearing of an upper denture Because the osteoma was so hard it was necessary to remove part of the cortex of the mandible with the specimen The same writer states,[2] "The development (of an osteoma) may occur in any part of the maxilla and mandible and arises from preformed bone, periosteum or retained cartilage cells from the embryonic chondroskeleton Growth is progressive, but slow, and the tumor is benign in character It starts spontaneously and is believed by many to be of traumatic but noninflammatory origin Its growth generally ceases with the termination of general skeletal development "



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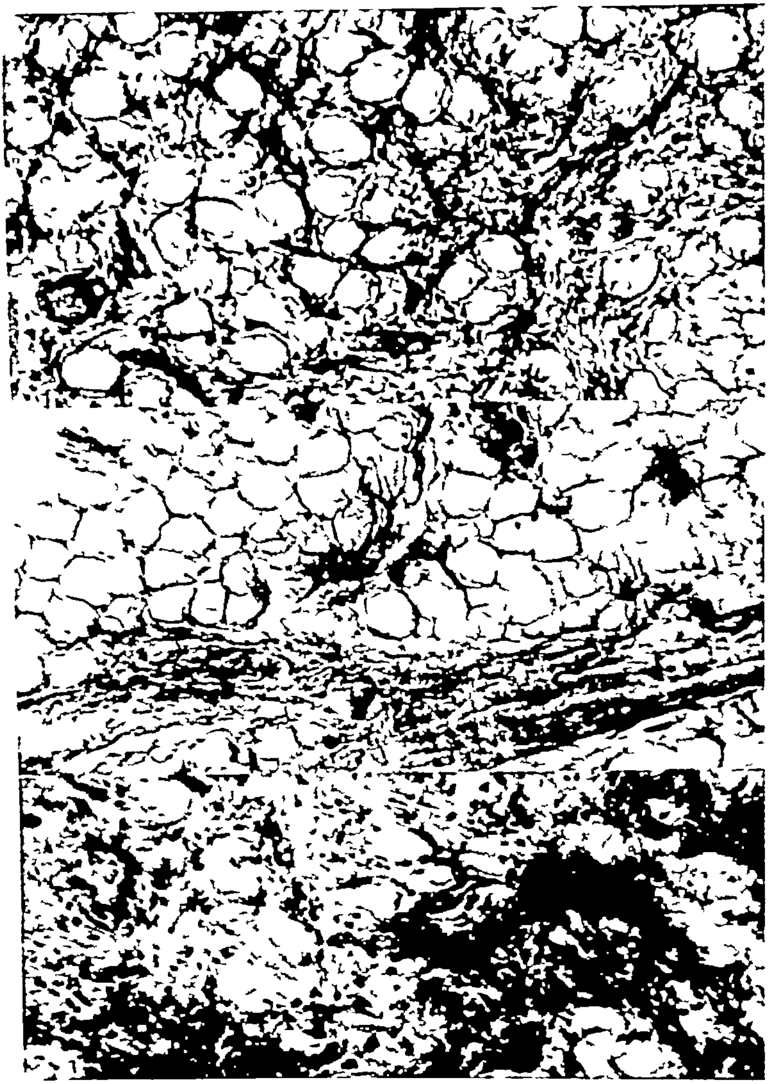

Fig 4 Case 2 Top—Photomicrograph (×160) of a representative portion of the original tumor removed in 1927 Adult-type fat cells are abundant but between these in places are elongated cells with fairly large and very deeply stained nuclei representing the sarcomatous element. Middle—Recurrent tumor of 1944 at this time entirely lipomatous and nonmalignant (×160) Lower—Representative area from the 1953 recurrence now somewhat more sarcomatous than in 1927 but still containing many adult adipose cells (×160)

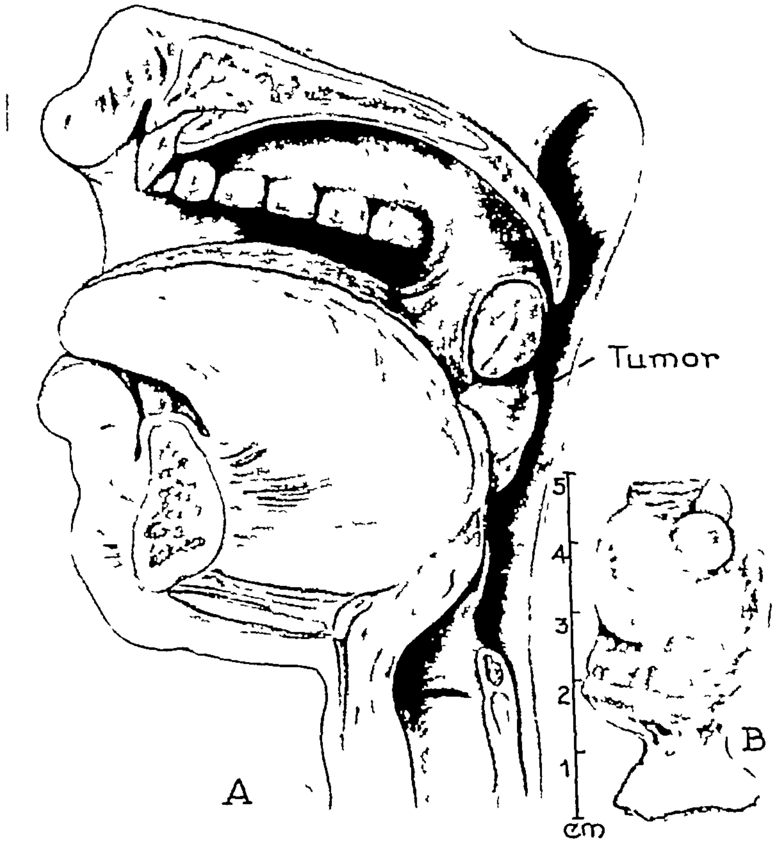

Fig 3 Case 2 Fibro-liposarcoma of dorsum of tongue extending into tonsil fossa

The pathology examination as recorded by Dr Hunter was as follows The pathological diagnosis of the tumor removed in 1927 was adeno myxoma with doubtful malignancy ”

Reviewed in late 1957 the histopathology proved to be identical with that observed in the recurrence of 1953 termed recurrent fibro liposarcoma

In 1944 a mass of yellow tissue divided into two parts by a cleft surrounded by a thin fibrous zone and measuring 4 5x3 5x1 cm was reviewed

Microscopically this proved to be principally fat cells of adult type, together with some mature collagenous type connective tissue Vascularity was not at all excessive There were no lipoblastic cells The pathologic diagnosis was submucous lipoma articular, perineal and mediastinal regions They generally first appear as rounded swellings of spontaneous origin, which grow steadily or rapidly until large or bulky masses result with prominent pressure symptoms They are usually encapsulated until recurrences develop as diffusely infiltrating, highly malignant and metastasizing processes"

Boyd[10] in discussing retroperitoneal liposarcomas says "Microscopically the greater part of the mass consists of adipose tissue, but here and there may be found areas of myxomatous tissue and sarcomatous formation It appears probable that these have developed primarily and that the tumor represents an embryonal type of tissue, rather than that they are due to a transformation of the lipoma"

MIXED TUMOR OF THE NASOPHARYNX

Case 3 Mrs D C M white age 52 In a general physical examination by Dr Eldon W Snow on Feb 10 1957 a swelling of the left tonsil area was noted It appeared as a fullness of the soft palate and posterior pillar which pushed the tonsil forward and medially The mass did not appear to change in size and on Oct. 27 1957 was explored by Dr Snow Upon removal of the normal tonsil the tumor immediately protruded through the posterior pillar It appeared to be of the consistency of cartilage which fragmented easily and was readily separated from the surrounding tissue A large fragment was removed for biopsy and the pathological examination by Dr Warren C Hunter revealed chondrosarcoma

X ray examination by Dr Arthur L Hunter revealed a large discrete opacity about 4 cm. in diameter protruding from the left lateral wall of the nasopharynx beyond the midline with no evidence of bone destruction X ray examination of the thorax was normal Otolaryngological examination showed the soft palate and left posterior pillar to be pushed forward by a large mass covered with normal mucosa protruding into the nasopharynx from the left side It extended almost to the midline and compressed the Eustachian orifice No other significant abnormality was found

Definitive surgery was carried out by the writer on Nov 21 1957 Under general anesthesia, the left external carotid artery was ligated below the lingual branch A tracheotomy was performed to facilitate anesthesia, and the hypopharynx was completely packed off A vertical incision was made through the left side of the soft palate beginning in the tonsil fossa and extending upwardly to the posterior edge of the hard palate Tumor tissue with a definite capsule was immediately encountered It was soon found that the tumor extended into the surrounding muscles extensively By sharp and blunt dissection the large neoplasm with a wide margin of surrounding normal muscle was removed in many pieces with a minimum of bleeding The largest fragment measured 5x4x3 cm In order to remove the tumor completely it was necessary to resect large portions of the left internal pterygoid muscle the palatine muscles and the posterior pillar The resulting cavity was bounded above by the Eustachian cartilage (not involved by tumor) and

In 1953, the specimen consisted of two tissues, one both smooth and rough surfaced, very soft white to red and measuring 1 3x1x0 5 cm, the other smooth everywhere soft, white to faintly pink and having dimensions of 3x2 5x1 5 cm The cut surfaces proved to be white to faintly yellow

Over a part of the larger tissue was a covering of stratified squamous epithelium along with underlying aggregates of lymphocytes The mass consisted of connective tissue and of fat and mingling with the latter were a good many cells of varying size and with hyperchromatic nuclei The cytoplasm lacked demonstrable vacuolization in the paraffin sections, yet their form otherwise and in a background of adipose tissue gave the impression that this growth must be considered as a recurrent fibroliposarcoma, and such was the pathological diagnosis Since all of the material had been embedded there was nothing available for fat staining (see Fig 4)

In a written consultation on this patient, Dr Simeon T Cantrell of Seattle, Wash, stated that he had never seen a similar tumor on the tongue, and that it was one of the very rare forms of mesenchymal sarcoma which has considerable radio-sensitivity He suggested that this patient should not be radiated unless the tumor should recur

At the present time there is no evidence of local recurrence or metastasis Obviously this tumor had a low degree of malignancy, as shown by its long duration and its recurrence at one time as a lipoma

A patient with a simple lipoma on the anterior surface of the tongue has been reported by Braunstein [6]

Saunders[7] in reporting a lipofibroma of the larynx presents an extensive bibliography on the subject of lipoma of the larynx Several of the cited cases of primary laryngeal lipoma showed extensions of the tumor to the epiglottis and valleculae One tumor originated on the left aryepiglottic fold and was diagnosed as myxolipoma with sarcomatous changes All of these tumors were removed surgically

Knowles and Hugill[8] have reported the case of a 12-year-old child who had a primary liposarcoma in the submucosa of the naso-pharynx The patient died with metastasis to the lungs, liver and brain

Lipomas are commonly seen in many parts of the body and are usually of no major consequence Ewing[9] states that "Liposarcomas are most frequent in the intermuscular, peri-

Boyd[11] states that a mixed tumor has two components, the first of which is the epithelial cell and the second, the spindle or stellate cell, separated by abundant intercellular mucoid material He states that in places this material may closely resemble or be identical in appearance with cartilage It was considered very fortunate that this tumor was of the mixed type rather than a chondrosarcoma Wirth and Shimkin[12] report a chondrosarcoma of the nasopharynx, which was very extensive and had a fatal outcome in spite of extensive surgical removal

Mixed tumors commonly arise in the major salivary glands, and also occasionally in aberrant salivary glands widely scattered over the whole of the oral mucosa If the tumor is completely removed by the first operation, the prognosis is generally considered to be quite favorable, however, "recurrence" may follow incomplete removal In order to be sure of total removal the tissue surrounding the capsule must be resected Malignant changes are uncommon The author observed in 1946 the removal by Dr Louis Clerf of a large mixed tumor of the nasopharynx by a transpalatine approach In reporting 33 malignant tumors of the nasopharynx, Hara[13] includes two mixed salivary gland tumors

In the presently reported case, there was no connection between the nasopharyngeal tumor and the deep lobe of the parotid gland, however, Morfit[14] reported 12 mixed tumors arising from the deep lobe of the parotid and presenting in the lateral pharyngeal wall as a large mass covered with normal mucosa Occasionally also the tumor presented below the horizontal ramus of the mandible The pharyngeal prominence is to be distinguished from an aneurysm or a large carotid body tumor External removal of the large parotid mass was recommended

Sonnenschein[15] has described two mixed tumors in the soft palate These were surgically removed and are rare in this location

MALIGNANT LYMPHOMA OF THE TONSIL

Case 4 Mrs K L white age 60 consulted her family physician on July 3 1957 because of a sore throat of two weeks duration His exam the base of the skull, laterally by the styloid process and carotid sheath, posteriorly by the longus capitis muscle, and anteriorly by the remains of the soft palate

The post operative course was uneventful except for trismus which has gradually improved

The pathological report by Dr Hunter of the original biopsy was The portions of tissue first seen had the color, consistency and cutting qualities of hyalin cartilage Sections contained nothing other than apparent cartilage and because of the atypical character of the nuclei the initial diagnosis was chondrosarcoma

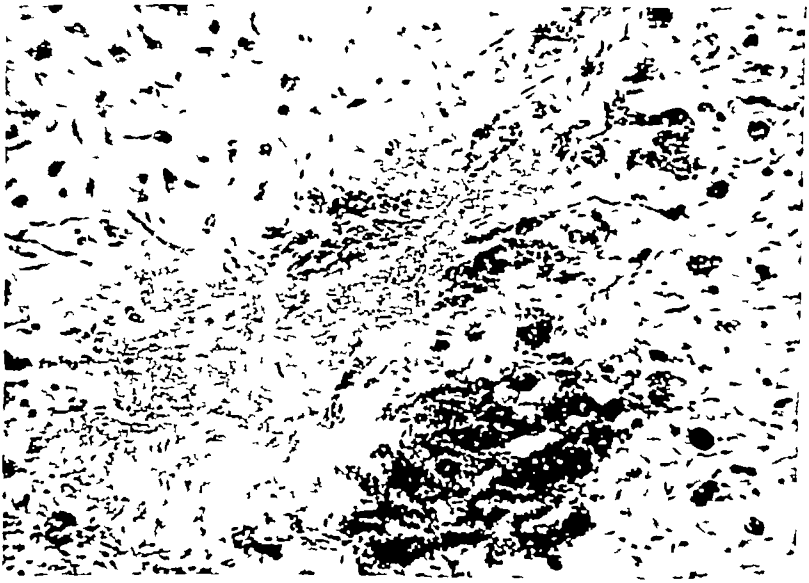

Fig 5 Case 3 Mixed salivary gland tumor (X160) this field contains many nests of epithelial cells relatively little matrix and no cartilage whereas the biopsy consisted entirely of atypical cartilage

The largest of the masses, removed on Nov 21 1957, appeared to be a partially encapsulated lobulated white tissue measuring 5x4x3 cm, cut with the consistency of cartilage and was white to yellow

Microscopically the growth consisted in large part of bluish pink to violet staining material rather poor in cells of apparent epithelial nature occurring in solid strands, and as small alveoli These had some resemblance to the alveolar epithelium of a serous type of salivary gland Mucus was not a component of the cells or the lumens of the alveoli None of the cells appeared to be of squamous type Embedded in surrounding connective tissue in close association with skeletal muscle and entirely away from the tumor were some lobules of a salivary gland of mucous type, unassociated with neoplasm

In view of the structure of the whole tumor as contrasted with the fragments making up the earlier biopsy the original diagnosis of chondrosarcoma was changed to mixed tumor of aberrant salivary gland" (see Fig 5) showed the soft palate and right pillars to be grossly normal with a gray membrane lining a normal appearing fossa In the right side of the neck, anterior to the sterno-cleidomastoid muscle was a freely movable smooth mass of rubbery consistency measuring about 10 cm in greatest diameter The remainder of the examination including an X-ray of the chest was negative X ray therapy was administered in divided doses to the throat and neck. The tumor responded well and examination on Oct. 3 1957 showed the tonsil fossa to be well healed and the mass in the neck to have completely disappeared

Malignant lymphomas of the throat and cervical lymph glands are rather common, and are usually considered to be best treated by irradiation

CARCINOMA OF THE TONSIL

Case 5 Mr M. O white, age 57 sought consultation because of a mass in his neck He stated that for several months he had visited various physicians in a large clinic because of a sore throat. He was told that he had an infection and was given various antibiotics which gave no relief Eventually the left side of his neck began to swell and an incision into this mass showed squamous cell carcinoma

Examination by the writer showed that a fungating tumor about 5 cm. in diameter occupied the left tonsil fossa. The soft palate and pillars were indurated and fixed and moderate trismus was present. The entire left side of the neck was greatly swollen and indurated The patient appeared to be in good general health otherwise

At that time he had already begun a course of cobalt radiotherapy under a competent physician For that reason, he was advised to continue the treatment, and that if the lesion in the tonsil was controlled radical surgery of the neck should be considered His further progress is not known.

Obviously, the prognosis in a patient such as this is discouraging

Early and small carcinomas of the tonsil can sometimes be completely removed by tonsillectomy If the tumor is more advanced, irradiation therapy is usually employed If the metastasis in the cervical lymph glands is not too far advanced, radical neck dissection is usually the best treatment if the primary lesion can be controlled

SUMMARY

The records of five patients having tumors in a tonsil or in the surrounding structures are presented The diagnostic and treatment problems are discussed and the literature is reviewed

ination revealed the right tonsil to be enlarged and displaced medially An enlarged anterior cervical lymph gland was present on the same side Because it was thought to be a peritonsillar abscess, an incision was made above the tonsil, but no pus was found Under antibiotic therapy, the tonsil decreased somewhat in size On Aug 13, 1957, the tonsil was removed and found to be extremely large

The pathological report by Dr Jeff Minckler was as follows The tonsillar tissue is submitted in three pieces ranging from 2 5 to 3 5 cm in their greatest dimensions The epithelial surface is identified on the larger specimen The surfaces are moderately fragmented and on sectioning much destruction of the tonsillar tissue is identified The entire tissue is mottled pale pink to red Nothing suggestive of a neoplasm is encountered

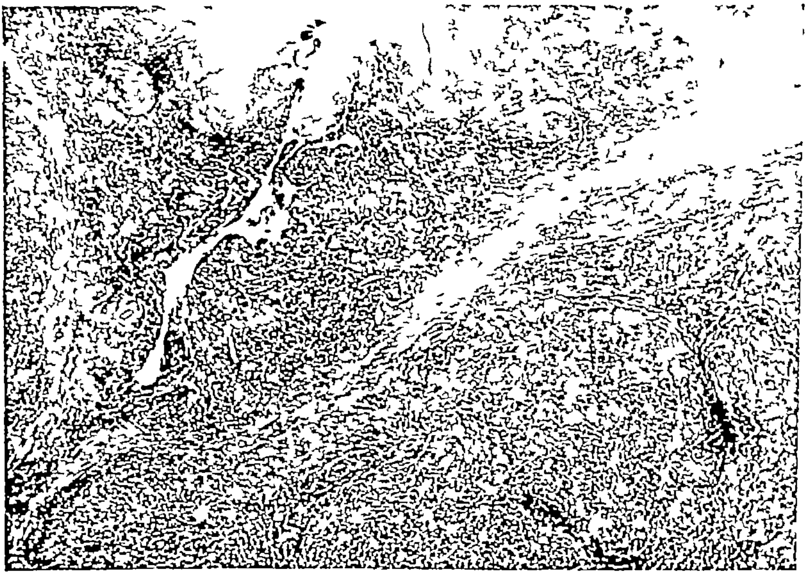

Fig 6 Case 4 At a 40X magnification the contrast between normal tonsil just below the epithelium of the crypt and the malignant lymphoma occupying the lower part of the field is quite evident

Microscopically the architectural pattern of the tonsil is altered by what is interpreted as a neoplastic process of the lymphoma group The predominant pattern is that of large follicle-like structures without distinct germinal centers composed of relatively uniform medium sized cells that have somewhat ill defined cytoplasmic outlines with suggestive tailed processes attached There is slight to moderate mitotic activity in these fields In selected areas there is somewhat more dense cellularity with somewhat larger darker staining cells and more apparent mitotic change There appears to be local infiltration of the capsular surfaces

Diagnosis Malignant lymphoma (lymphosarcoma) of the right tonsil (see Fig 6)

The otolaryngological examination by the writer on Aug 16 1957

SINUS SYMPTOMS ORIGINATING FROM MODERN FLIGHT[*]

LT COL STANLEY H BEAR,

USAF (MC)[†][‡]

With the advent of a new era in aviation, man is ever attaining higher altitudes and traveling at faster speeds In so doing, he is encountering physical problems which interfere with his best performance and well-being One of the vital problems is the involvement of the sinuses due to barotrauma, a condition more commonly known as aerosinusitis

Aerosinusitis is an acute or chronic inflammation of one or more of the nasal accessory sinuses produced by a barometric pressure difference between the air or gas inside the sinuses and that of the surrounding atmosphere It is commonly characterized by congestion and inflammation of the lining structures Mucosal or submucosal hemorrhage may occur[1]

There are two general types of aerosinusitis which may develop the non-obstructive, which is due to the collection of mucous secretions in the ostei, or the obstructive type, which has three degrees depending upon the severity Most chronic cases will fall into the latter group and are usually of the third degree

During the past two years, I have examined, in our clinic, 48 cases of aerosinusitis of the chronic obstructive type An evaluation has been made of the incidence, predisposing factors producing the physiological disturbances, signs and symptoms, pathology, X-ray findings, treatment and sequelae

The incidence of aerosinusitis is difficult to evaluate in

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[†] From Surgical Service 3810th USAF Hospital Maxwell Air Force Base Alabama

[‡] The opinions expressed are those of the author and do not necessarily represent the opinions of any department of the Department of Defense.

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624 Medical Arts Building

been properly briefed on the awareness of difficulty in flight, such as making slower descent and the use of the Valsalva maneuver, especially in cases of Eustachian tube involvement, however, the Valsalva maneuver is of little benefit in sinus obstruction and will not lessen the degree of symptoms Several fliers with more than 1,000 hours in conventional aircraft experienced symptoms on their very first jet flight In two instances, symptoms occurred during every descent in jet aircraft, yet they never experienced any difficulty in flying slower conventional aircraft

There are two main factors which tend to produce difficulty in flight These are a rapid change in barometric pressure, plus a predisposing factor which interferes with the air or gaseous change between the environment or nasal cavity and that of the sinus cavity The pressure change at the various altitudes is noted on the following table [5]

TABLE I

Altitude Based on United States Standard Atmosphere
(From Armstrong)

Altitude (Feet)	Pressure (mm Hg)
0	760
5 000	632 30
10 000	522 60
20 000	349 10
30 000	225 60
40 000	140 70
50 000	87 30

In general, on ascent from sea level to 5,000 feet, there is a decrease in barometric pressure from 760 mm Hg to 632 30 mm Hg, one-sixth atmosphere, and on ascent to 18,000 feet there is a decrease to 360 mm Hg, or one-half atmosphere The change is reversed on descent, therefore, it is especially noted that the greater differrential pressure change is noted at the lower altitudes This effect is more pronounced as the speed or rate of change is increased and greatly altered if a predisposing factor in any way interferes with this change Proetz[6] states that a reduction of one-fifth atmosphere (152 mm Hg) pressure is ordinarily well tolerated by the mucosa, any group of cases We were unable to correlate the incidence, because the cases were referred for final disposition after failing to respond to primary treatment The exact number of acute cases, before becoming chronic, was undetermined Campbell[2] reported on 35,000 simulated flights in the altitude chamber, where a direct control of all cases was able to be made, and found an incidence of 1 9 per cent McGibbon[3] noted 18 cases in 1000 chamber flights, or incidence of 1 8 per cent

One large airline during a one-year period, noted a major discomfort in its passengers from all causes due to air travel, averaged about eight or nine per 1,000[4] The incidence of sinus and ear distress reported varied from 0 5 to eight per 1,000 passengers carried, and it was felt that this rate would have been higher if all passengers who experienced sinus or ear distress had reported it Unfortunately, the number of flights made in pressurized aircraft was not differentiated from those in unpressurized aircraft

To our knowledge, there has been no report made on the incidence of aerosinusitis resulting from jet aircraft flight Of the 48 individuals we examined, 38 experienced symptoms of aerosinusitis in pressurized jet aircraft Of the remaining ten cases, six occurred in pressurized conventional aircraft for a total of 44 cases in pressurized aircraft There were four cases occurring in unpressurized conventional aircraft

What are the factors producing this change? It was interesting to note that of the 48 aircrew members, there was no direct correlation with the flying time The minimum number of hours flown by any of the pilots was approximately 50, and the maximum number of hours was over 5,000, when the symptoms became incapacitating There were four cases occurring in the 0-500 hour group, eight cases in the 500-1,000 hour group, 13 cases in the 1,000-1,500 hour group, 16 cases in the 1,500-3,000 hour group, and seven cases occurring in personnel with more than 3,000 hours of flying time

The four cases which developed in the 0-500 hour group all occurred during the flight training period in unpressurized conventional aircraft In all instances the individuals had between 12,000 feet and ground level Some occurred at an altitude of less than 5,000 feet The condition seemed to be aggravated by the rate and duration of the pressure change

There are many predisposing factors which, in combination with a rapid barometric pressure change, either on ascent or descent, will produce an acute obstruction to the sinus passage with resulting aerosinusitis The more common, in decreasing order of occurrence, are

TABLE II

Predisposing Factors in Etiology of Aerosinusitis

Deflection of Nasal Septum (More than 50%)	23
Hypertrophy of middle turbinate with encroachment of middle meatus and nasofrontal duct orifice	14
Nasal allergy	10
Upper respiratory infection	7
Polyps in middle meatus	7
Mucocele	2
Septal spur	1
Hypertrophic rhinitis	1
No abnormal finding at examination	1
Cyst on floor of maxillary sinus	1
Vasomotor rhinitis	1
Osteoma over sinus orifice of nasofrontal duct	1

In some cases it was noted that more than one factor was prevalent, such as allergy and nasal polyps, or deflection of the nasal septum with encroachment of the middle turbinate on the nasofrontal duct, thus, the total on the above chart will, in some instances, have more than one etiologic factor It is important to note that deflection of the septum was high in over two-thirds of the cases This resulted in the impingement of the middle turbinates laterally over the opening of the nasofrontal duct with encroachment on the duct orifice This was a significant finding in nearly 50 per cent of the cases The one case of osteoma was located at the orifice of the superior part of the nasofrontal duct and caused almost complete collapse of the mucosa lining the duct This acted as a suction valve on descent and would obstruct the orifice, producing severe symptoms Nasal allergy and polyps were present in seven of the cases They were obstructing the middle meatus in all instances The case of vasomotor rhinitis but when in much excess of this may be expected to be followed by hemorrhage, either mucosal or submucosal Behnke[7] found that if a sinus opening is obstructed and an increased pressure of one to two pounds transmitted to the body tissues and circulating blood, an area of relatively decreased pressure is produced in the air spaces This results in a cupping action in the cavity and a vascular congestion of the mucous membrane Tension is produced on the cells of the living membrane, and the blood vessels distributed in tissue surrounding the occluded space Pain is present in and around the involved area, associated with congestion and hemorrhage

Today most modern pressurized aircraft fly at a cabin altitude of approximately 8,000, and those of future jet operations will be at or near this altitude on long flights There is only a slight difference on ascent or descent of selected cabin altitude from that of the plane, therefore, from 8,000 feet to ground level, pressurization will have little beneficial effect on the individual crew member or passenger At the present time C A A Regulations allow a maximum rate of change of cabin altitude equivalent to approximately 300 feet per minute[8] This applies to both ascent and descent In future jet aircraft operations there are times when a faster rate of descent may be produced through loss of pressurization, faulty pressurization valves, instrument approaches, or in cases of fuel starvation Any one of these factors will necessitate a more rapid rate of barometric pressure change, and added to a predisposing intrinsic factor in the passenger or crew member, sinus symptoms will likely result

It is worthy to note at this point that there is a difference in the pressurization between military jet aircraft and those of anticipated commercial design At lower levels, the altitude of pressurization is approximately 12,000 to 13,000, rather than 8,000 feet, and the differential pressure at high altitudes is usually the maximum of 5-plus pounds per square inch, while the commercial planes are designed for 8-plus pounds per square inch for operation

In all the cases in our series, there were only a few occurring above 15,000 feet cabin altitude The majority occurred sinus and four with both frontal and maxillary sinuses involved The fourth major symptom was that of a feeling of pressure over the involved sinus, and occurred in seven cases The fifth predominant symptom or sign was evidence of a delayed bleeding, *usually of old blood, occurring 24 or* more hours after primary involvement This was noted on expectoration upon arising in the morning, or on blowing the nose, when blood-streaked mucous would be present The lesser symptoms are noted on the Table above

This discussion does not include the ethmoids and sphenoid sinuses, because no case of aerosinusitis occurred where only

TABLE III

Subjective Symptoms Experienced with Reference to Involved Sinus

	Frontal	Maxillary	Frontal and Maxillary
Sharp pain from descent	23	7	2
Sharp pain from ascent	0	1	0
Pain from ascent and descent	3	0	4
Generalized headache	2	0	3
Pressure over sinus	3	2	2
Nasal obstruction	4	3	2
Bleeding (delayed)	4	0	2
Blurring of vision	3	0	0
Lacrimation	2	0	0
Swelling of upper eyelid	1	0	0
Rhinorrhea	0	1	1
Plugged ears	3	0	1

the ethmoid and sphenoid was primarily involved When there is severe involvement of either maxillary or frontal sinuses there may be associated involvement of the ethmoid sinus, but it is not felt to be the cause of the primary symptom complex This was also the finding of other authors[2,3] As previously noted, the frontal sinus was most frequently involved, next, the frontal and maxillary, with the maxillary sinus the least involved Campbell and McGibbon[2,8] also found the frontal sinus to be the most frequently involved, while Wright, in his series, found the most frequent site of involvement to be the maxillary[9] The reasoning for greater involvement of the frontal sinus is based on the greater length of the nasofrontal duct and its tortuous path and small caliber was in a cadet in training period, and was aggravated by an emotional problem On flying, his nose would completely obstruct, causing pain in sinus He was recommended for psychiatric evaluation and elimination from flying duties

The above conditions were present even in a select group of individuals Aircrew members were given rigid acceptance physical examinations, however, in most instances the deformities were acquired or developed during their career In addition, most pilots had been indoctrinated in the preventive medical aspects of flying and proper care of themselves during flight The average air passenger is not as well indoctrinated in active and preventive measures that can be performed while flying Many prospective passengers may have a nasal allergy of sufficient degree to be symptomatic on descent, active sinus pathology, upper respiratory infection, nasal obstruction of one sort or another, or a marked degree of apprehension and anxiety All of these act as predisposing factors, and when subjected to a rapid change of descent will produce aerosinusitis of one degree or another On ascent, the predisposing condition is basically intra-sinus, or in the osteum or duct of the sinus, while on descent the difficulty present is in the nasal cavity or surrounding structures in the area of the duct orifices leading into the sinus, as noted in the previously mentioned causative factors From these findings one is able to deduce whether the difficulty will be encountered on ascent or descent, or both

There are many symptoms produced by aerosinusitis, but the predominant symptom in most cases is pain located over the involved sinus It is described as being sharp, lancinating in character, non-radiating and occurring most often during descent The frontal sinus was involved in 23 instances, the maxillary sinus in seven, and both frontal and maxillary in two instances (see Table III)

The second most common symptom was that of nasal obstruction This occurred in nine cases and was almost equally divided, with involvement of either the frontal or maxillary sinus There were seven cases of pain on both ascent and descent, with three associated with involvement of the frontal orifice This results in free bleeding from the mucosa surface or submucosally, producing submucosal hematoma This was noted in four of our cases Campbell was able to demonstrate the same findings in his experiment with a dog in an altitude chamber

The treatment of aerosinusitis usually falls into one of two categories the acute phase, and the chronic or persistent type The acute stage is treated conservatively with treatment initiated as soon as possible after symptoms occur Treatment consists in the use of vasocontrictor sprays and packs, steam inhalation, antibiotics prophylactically, and anodynes for control of discomfort In severe cases, applicators of 5 per cent cocaine and 1 per cent ephedrine are placed directly in the middle meatus at the opening of the nasofrontal duct of the side involved Depending on the time interval following initiation of the first symptoms, most cases will respond to conservative management It is worthy of mention that the longer the interval before treatment is begun, the more difficult it is to obtain patency of the involved sinus

TABLE IV

X ray Findings in Aerosinusitis

FRONTAL	
Clouding frontal	19
Submucosal hemorrhage	5
Polypoid hyperplasia of sinus mucosa	3
Mucocele with hemorrhage	2
Osteoma at orifice of nasofrontal duct	1
Large ethmoid cell at orifice of nasofrontal duct	1
No sinuses present	1
Fluid level	1
No abnormal findings	1
MAXILLARY	
Clouding	5
Polypoid hyperplasia	3
Retention cyst floor of maxillary sinus	2
BOTH FRONTAL AND MAXILLARY	
Clouding	8
Hyperplastic scarring	2
Polypoid mucous membrane	2

of opening The opening of the maxillary sinus is larger and may have accessory openings Von Diringshofer[10] states that more involvement is expected in individuals with large frontal sinuses, but in one of our cases with severe frontal pain there was only a small frontal cell and no development of the frontal sinuses

X-ray examination is an important phase in the evaluation of aerosinusitis When possible they should be taken immediately as well as several days later if symptoms and signs persist It has been noted in cases where there is either mucosal or submucosal bleeding that definite delineation of the area involved may not be demonstrated until the bleeding is organized into a hematoma One of the most difficult X-ray diagnoses to make is submucosal hemorrhage It is very helpful to have previous X-ray films to help differentiate from polypoid hypertrophy or polyps The latter is uncommon in the frontal sinus, otherwise, the clinical history must be evaluated to rule out the presence of nasal polyps and allergy This was the opinion of Coche[11], also in four of our cases of bleeding with hematoma found on X-ray The views used in routine evaluation are Caldwell, Waters, and lateral views When indicated, laminograms are beneficial in making a differential diagnosis (see Table IV)

There were two cases in which more than one finding was made The pathology of aerosinusitis varies, depending on the etiologic factor and the degree of intra-sinus or naso-frontal duct changes The histologic structure of the mucosa is a continuation of the nasal respiratory mucosa with slight variations The submucosa is thinner and tends to blend with the fibrous periosteum of the underlying bony sinus wall The epithelium is a thinner cuboidal-like, stratified ciliated structure The resulting sinus mucosa changes can vary from thickening of the mucosa either inflammatory or polypoid, or there can be presence of fluid, blood, mucous, or purulent secretions in the chamber of the sinus In some cases, mucoceles will be present while others have osteoma in the cavity covered with a very thin mucosa Probably the most marked change is that noted in rapid changes of barometric pressure with the complete occlusion of the sinus partial turbinectomy of the anterior third of the middle turbinate because of polypoid hypertrophy encroaching on the opening of the nasofrontal duct There was one case of vasomotor rhinitis which was due to an emotional disturbance, and it was recommended that the individual have psychiatric evaluation and be eliminated from flying duties

As a group, chronic cases of aerosinusitis must have treatment directed to the precipitating factor, and in most instances the condition can be corrected only by surgical or allergic management It is easy to ascertain that conservative management will be of little avail where these conditions exist Many of the predisposing factors would not require surgical intervention if the individual were not flying, however, when required to fly either as passenger or aircrew member, surgical correction is necessary to alleviate the condition

Of the 48 cases, there were three cases which were entirely unsuccessful following treatment two of these cases showed marked nasal polyposis and polypoid hypertrophy of the turbinates and an underlying allergic condition The individuals were unable to fly without repeated bouts of aerosinusitis The other case was that of the vasomotor rhinitis, for which no treatment was indicated as it was felt to be due to an emotional basis There were three cases in which the individuals were able to fly, but at intermittent intervals would still experience symptoms, usually not to the degree of incapacitation from flying duties Two of these cases were allergic rhinitis with polyposis, while the third case was that of recurrent upper respiratory infection This individual is still undergoing treatment to determine the etiology of his infection. The remaining 41 cases have been returned to flying duty and have experienced no difficulty in most cases, and minimal symptoms in a few cases which did not interfere with duty performance All cases were followed for a minimum of one year, however, due to loss of contact and follow-up in some cases the incidence of recurrence may have been slightly higher One case has recently been discharged from the hospital following frontal sinus surgery for submucosal hemorrhage and obstruction to the nasofrontal duct He has

In our series, almost all the cases were of a chronic nature, having been referred when conservative management failed, or when there was a recurrence of the condition at frequent intervals Following is a table showing the various treatments utilized in the 48 cases of our series

In several cases, more than one procedure or combined procedures were necessary to correct the condition In 20 cases, conservative management was used which consisted of antibiotics when indicated, vasoconstrictors and steam inhalation, or minor surgical manipulation to produce a patent osteum of the involved sinus The conservative treatment was mainly combined with infraction of the middle turbinate which was necessary in 13 cases, and in cases of post-polypectomy to maintain normal drainage, however, there were 19 cases in which it was necessary to perform a submucous resection (Killian type) In all but seven of these cases, the obstruction was located in the region of the middle turbinate, and in several cases following resection, infraction of the middle turbinate was combined in the treatment Four cases of frontal sinusotomy, by the Lynch approach, were necessary to remove the frontal sinus pathology and obtain a patent nasofrontal duct Allergic management was utilized in five cases with fair results In one case of an antral cyst, an antral window was performed with curettement of the cyst Two cases of recurrent purulent infection of the sinus were treated by irrigation, one was of the frontal sinus, the other, of the maxillary sinus Two cases were surgically treated by

TABLE V

Treatment of Aerosinusitis (Chronic Cases)

Conservative (antibiotics, vasoconstrictors, steam inhalation)	20
Submucous resection	19
Infraction of middle turbinate	13
Polypectomy	7
Allergic management	5
Frontal sinusotomy (Lynch approach)	4
Antral window	1
Vasomotor rhinitis*	1

*Vasomotor rhinitis—due to emotional disturbance Recommended elimination from flying duties

MANAGEMENT OF SINUSITIS IN CHILDREN *

CLIFFORD F LAKE, M D ,†
Rochester, Minn

Sinusitis, either alone or associated with some other inflammatory process in the respiratory tract or related areas, occurs frequently in childhood Although this fact has been demonstrated and reported many times in the past, it seems that in this age of antibiotics its re-emphasis is indicated

Dependence on antibiotics alone, and especially on short courses of them, during acute respiratory tract infections may only modify or mask associated acute sinusitis

Failure to examine the nose and nasopharynx completely when possible, or to obtain roentgenologic views of the paranasal sinuses, often causes failure in diagnosis Birdsall[1] stated that nasal sinus infection in children is common, but is often overlooked because of its usually insidious onset, the lack of definite symptoms, and the difficulty of examining the affected parts

From the ages of four or five most children who are co-operative can be given satisfactory nasal examination Children this old frequently will be co-operative on nasopharyngeal examinations with the small to medium-sized mirrors A brief explanation of what is about to happen, and a demonstration of quiet rhythmical breathing often will convert a skeptical child into a most co-operative youngster If the tongue depressor and nasopharyngeal mirror are introduced simultaneously, the number of satisfactory nasopharyngeal examinations will be increased This method of introducing the instruments relieves the child of the "double jeopardy" of separate instrumentations

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†From the Section of Otolaryngology and Rhinology Mayo Clinic and Mayo Foundation The Mayo Foundation Rochester Minn is a part of the Graduate School of the University of Minnesota

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not been returned to flying duty, but exhibits a patent duct at the present time and will be given trial indoctrination in the altitude pressure chamber to see whether his results have been successful before returning to full flying duties

In all cases of aerosinusitis, treatment is directed to removing the etiologic factor as well as the existing condition

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several days before attempting therapy directed to the nose Antihistaminic drugs are of particular value in cases with a history of vasomotor or allergic rhinitis

Treatment directed to the nose usually is a matter of personal choice Prolonged use of vasoconstrictors often produces the familiar rebound phenomena Application of argyrol packs to the middle meatus and in the nasal chamber, followed by gentle suction, may prove of value in the removal of purulent secretion from the nose and sinuses In some children lavage of the maxillary sinus via the natural ostium can be carried out after the acute edematous stage has subsided

In an instance of acute ethmoiditis with external manifestations, as is found occasionally in a young child, surgical drainage may be necessary, however, if seen in the early stages this situation will usually respond to antibiotic treatment

Heat applied to the area over the involved sinus or sinuses may afford some relief of pain, however, sometimes it may exacerbate the pain Increasing the humidity in the patient's bedroom and making him comfortable are beneficial in his general care

During his course of treatment the patient should be reexamined for conditions which may have influenced the onset of the sinusitis or the application of therapeutic measures Enlarged adenoids, septal deflections, and allergic changes in the nasal mucosa are commonly occurring factors predisposing to acute sinusitis

The status of the patient's general health should be investigated Whatever general measures are necessary to improve it should be carried out, also it may be necessary to remove enlarged adenoids or a septal deflection to gain final resolution of the disease

Roentgen therapy has been used successfully in the treatment of acute or subacute sinusitis in the past Laing[4] reported treatment with Roentgen therapy in 900 cases of subacute sinusitis in children, 639 of whom were cured during

Obviously the anatomic development of the paranasal sinuses in accord with age has an effect on the sites in which infection may develop In older children the roentgenologic views are particularly helpful in localizing the site of infection Maresh,[2] in a study of routine roentgenograms of the sinuses of 100 children who were followed from birth to maturity, observed many variations in the size and shape of antrums, ethmoid cells, and frontal sinuses

DIAGNOSIS AND SYMPTOMATOLOGY

Sinusitis should be included in the differential diagnosis when symptoms of prolonged rhinorrhea, coughing, frequent sniffling, or throat clearing are present A history of recurrent respiratory infections, otitis media, secretory otitis, and sore throats should suggest the possibility of the presence of sinusitis Wishart[3] stated that the most frequent complaint in an otherwise healthy child in whom sinusitis is discovered is repeated head colds

In cases of small children the history obtained from the parents and the objective findings on examination, with the findings from roentgenologic examination in some instances, usually will suffice in making the diagnoses Older children often can contribute to their history, and should be encouraged to do so Frequently such children describe their symptoms accurately, especially when pain is present in acute sinusitis or in a flare-up of chronic disease

In the history, allergy affecting either the patient or his family should not be overlooked

MANAGEMENT OF ACUTE SINUSITIS

The best basis for management of acute sinusitis in children is consideration of the child as a whole and the severity of his infection A culture of the nasal secretions should be made and tests of sensitivity to antibiotics performed The child's reaction to obtaining the material for culture from his nose may indicate the degree of co-operativeness to be expected in carrying out local treatment If the infection is severe enough to warrant the use of antibiotics one may wait sinuses and ethmoids, particularly the left antrum. Skin tests were made which showed sensitivity to cat hair cattle hair goat hair, house dust, mixed feathers pyrethrum and giant and small ragweed

A diagnosis of allergic rhinitis and sinusitis was made The treatment consisted of giving the child an antihistaminic drug for two weeks, after which he was re-examined The nose then appeared to be normal with no evidence of any unusual discharge New roentgenograms showed marked clearing of the paranasal sinuses

Comment This case is an example of sinusitis superimposed on hay fever, and illustrates the improvement which occurred from the use of an antihistaminic prescription during the recession of the hay fever season Further care in regard to the allergic manifestations was advised

Case 2 A seven-year-old girl was registered at the clinic Nov 8 1957 She had had pneumonia approximately two months prior to her registration After five days in the hospital and two weeks at home for recovery she had returned to school, but after two days in school left otitis media developed To combat this ear infection she had been given antibiotics for a few days (The exact type of antibiotic and the number of days that it was given could not be determined at the clinic) Approximately a week later the patient developed a sore throat and a course of penicillin had been administered

On Oct. 30, the child had been seen in consultation by an oto-rhino-laryngologist A diagnosis of sinusitis had been made nasal irrigations had been carried out and she had seemed to improve On Nov 6 however she complained of a sore throat again and her trip to the clinic followed

She was first examined in the Section of Pediatrics Only normal findings resulted from general examination a roentgenogram of the lungs blood counts urinalysis and electrophoresis of serum protein

The child was examined in the Section of Otolaryngology and Rhinology, and her eardrums were found to be intact although the left showed slight infection from the recent acute otitis media Her hearing of tuning forks seemed normal The nose looked clear on examination, and no pus was visible on anterior rhinoscopy The turbinates were only slightly congested Roentgenograms of the child s sinuses showed involvement, particularly of the antra and especially on the left. The tonsils had been removed and the nasopharynx contained only a minimal amount of lymphoid tissue A culture of the nasal secretion was negative

It was thought that this patient's disorder was sinusitis the diagnosis depending largely on the history and on the appearance of the roentgenograms of the sinuses A two week trial of antibiotics was prescribed and the patient was advised to return at its conclusion

She did return at that time On examination her nose appeared normal and in roentgenograms her sinuses seemed clear The child was feeling well.

Comment This is a case of recurring upper respiratory infection, sore throats, and otitis media, in which a diagnosis of sinusitis was made largely on the history and roentgenographic findings The response to a two-week course of an one series of treatments, however, with the knowledge of risks involved in exposure to radiation I prefer not to use it for children

MANAGEMENT OF CHRONIC SINUSITIS IN CHILDREN

Adequate treatment may include several types of therapy, and the physician should not limit himself to an inflexible routine, rather, he should avail himself of all procedures, and use them as the situation demands, to restore the paranasal sinuses to their normal physiologic state

The treatment of chronic sinusitis follows the same principles in using antibiotics and intranasal therapy which were mentioned in the treatment of acute sinusitis Lavage of the maxillary sinus via its natural ostium can be accomplished in many older children

If surgical treatment is necessary it usually can be done intranasally, except for most instances in which external manifestations exist

The patient's general health should be evaluated A search for predisposing factors should be made, and their eradication accomplished, and again, the history of allergy in the patient or his family should not be overlooked The rather special problem of chronic sinusitis, associated with bronchiectasis, is not within the scope of this presentation, but the possibility of a co-existing bronchiectasis must be ruled out in all cases of chronic sinusitis

REPORT OF CASES

Case 1 An 11 year-old boy was registered at the Mayo Clinic on Sept 26 1957 His complaint was that sneezing, itching of the eyes, and nasal discharge had persisted for one month After a general examination in the Section of Pediatrics an ear, nose, and throat examination was requested

In the Section of Otolaryngology and Rhinology, examination of the ears revealed no abnormalities Examination of the nose showed much thick, sticky mucoid discharge on both sides particularly on the left some of which was yellowish and obviously mucopurulent The turbinates were moderately congested on both sides Pus was demonstrated coming from the natural ostium of the left antrum The tonsils had been removed There was a thick mucoid discharge in the nasopharynx, along with some mucopurulent material

Roentgenograms of the sinuses showed thickening about the maxillary rhinitis on the paternal side of the family The child had been taking an antibiotic of an undiscoverable type for 11 days prior to her admission for examination.

On examination of the ears the tympanic membranes were intact with very slight redness on the right The nasal septum was straight There was mucopus on both sides of the nose The tonsils were of size 2 on the basis of 1 to 4 The nasopharynx was examined with a mirror and a good view was obtained it was noted that an adenoid blocked most of the choana. On roentgenograms of the sinuses both antra were diffusely cloudy A culture of the nasal secretions was reported as showing usual flora

The patient was given penicillin for ten days At the end of that time the nose looked clear and no discharge was noted on examination of the nasopharynx Roentgenograms showed clearing of the paranasal sinuses

Arrangements were made for removal of the tonsils and adenoids this was done June 15 1956 After the operation the child got along well and was dismissed June 21, 1956

The child was observed a year later during the course of a common cold, however the cold cleared in eight days without complications or recurrence of sinusitis

Comment This case is an instance in which an enlarged adenoid obstructing the choana seemed to play an important part in the persistence of the patient's nasal symptoms and sinusitis

SUMMARY AND CONCLUSIONS

The occurrence of sinusitis in childhood deserves re-emphasis A short course of antibiotics may only modify or mask an acute sinusitis during the course of an upper respiratory infection Examination of the nose and nasopharynx should be complete when at all possible The value of roentgenograms and the history obtained from the parents and the child is great

The foregoing diagnostic principles and a discussion of the management of acute and chronic sinusitis in children have been illustrated in reports of four cases

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antibiotic was excellent, and the roentgenograms which were taken at the end of this treatment illustrated marked clearing within the sinuses There was no history of allergy in the family of the patient

Case 3 A six year old boy was registered at the clinic Nov 28, 1956 He had had persistent nasal obstruction for at least a year or so Infections of the upper part of the respiratory tract had been frequent and he had had pneumonia in 1952 There was no history of a definite allergic background but the patient's mother had had mild vasomotor rhinitis

In the general examination nothing out of the ordinary was found except mild obesity He was referred to the Section of Otolaryngology and Rhinology Our examination revealed the tympanic membranes to be intact, but they appeared slightly dull and his hearing seemed to be reduced very slightly through the entire range in both ears An audiogram showed very slight bilateral conductive deafness On nasal examination the nasal airways seemed to be open, however, mucus was pooled on the nasal floor, and when this was removed the adenoid could be seen obstructing the choana The tonsils were enlarged (grade III, on a basis of 1 to 4 with one being slightest), and combined tonsillectomy and adenoidectomy was advised The operation was carried out Nov 30 1956, and large masses of adenoid, and the tonsils were removed

The patient then got along very well until three weeks later when he developed an upper respiratory infection On examination a large amount of pus was observed in each nasal passage A culture of the discharge was reported as showing usual flora Tetracycline (achromycin) was prescribed, and the child's nose cleared nicely after a ten days' trial

The patient was again seen on January 23 1957, with a report that a cough had developed two days previously, and he had coughed most of the night prior to his examination His case was followed for several weeks, but the situation did not clear, and a culture again was made of the nasal secretions, this time showing many Hemophilus influenzae organisms Electrophoresis of serum protein gave findings within normal limits Roentgenograms of the sinuses showed cloudiness throughout all of them The patient was given a preparation of streptomycin with dihydrostreptomycin (distrycin) 500 mg twice daily for ten days and therapy directed to the nose was begun with shrinkage and suction and application of argyrol packs to the middle meatus on each side This was carried out for two weeks, after which the nose was clean the child was breathing freely and roentgenograms of the sinuses showed marked improvement, there being only a minimal amount of thickening in the left antrum Clinically the child was well

The case has been followed since and during one more upper respiratory infection the boy has gotten along well, with no further recurrences of his sinusitis

Comment This case illustrates the need in many instances of treatment to the nose as well as antibiotics in order to clear a sinusitis

Case 4 A 4½ year old girl was registered at the clinic May 3 1956 A history of repeated prolonged colds worse in the Winter months was obtained She had less difficulty during the Summer and her symptoms were not related to the hay fever season There was a history of allergic nasion, the chisel may force the ends of the fractured bones into the lumen of the sinus, causing frontal sinusitis

FRONTAL SINUS RELATIONSHIPS

At the *nasal notch* of the frontal bone, the floor of the frontal sinus is normally at the level of the glabella, but in some cases, it may extend as far down as the middle-third of the nasal bones (over-developed sinus), or it may stop short of the glabella (under-developed sinus)

OVERDEVELOPED FRONTAL SINUS

When the frontal sinus extends beyond the glabella, its floor is attached directly to the inner surfaces of the nasal bones, which in this instance become part of the anterior wall of the sinus (see Fig 1)

Thus, manipulations of the nasal bones at the nasion may injure the frontal sinus A natural protection is given by the fact that the periosteum, which covers the posterior surface of the anterior wall of the frontal sinus, is tough and loosely attached Its toughness gives it a good deal of resistance to cutting by sharp instruments, and its looseness renders it easily detachable at the slightest pressure These two favorable conditions form a very valuable protection against accidental entry into the lumen of the sinus when an ostectomy is performed

X-ray studies will give valuable information about the size and extent of the frontal sinus and its relationship to the nasal bones

UNDERDEVELOPED FRONTAL SINUS

When the frontal sinus is not well-developed, it will stop short of the glabella, and a block of compact bone will be found where the sinus is normally located At the nasion this block of compact bone fuses with the nasal bones, the frontal processes of the maxillae, the bony nasal septum, the frontal spine and the nasal notch of the frontal bone, to form a huge block of solid bone, which will make the ostectomy a difficult procedure

ANATOMICAL OBSERVATIONS FOR RHINOPLASTIC SURGERY *

ROMEO A LUONGO, M D ,
and
ROMEO A LUONGO, JR , M D ,
Philadelphia, Pa

ANATOMIC RELATIONSHIPS AT THE NASION

The squama of the frontal bone projects downwards, at the midline, to form the *nasal part* The lower margin of the nasal part, which is beveled, rough, uneven, and serrated, is called the *nasal notch* The *upper margins* of the nasal bones and of the frontal processes of the maxillae imbricate, like shingles, upon the beveled portion of the nasal notch

From the center of the nasal notch, the *nasal process* projects downwards and forwards underneath the upper margins of the nasal bones and the frontal process of the maxillae The *frontal spine* extends below farther than the nasal process itself, and it becomes fused with the perpendicular plate of the ethmoid posteriorly, and with the septal crests of the nasal bones anteriorly to give the bridge of the nose a solid support

This type of construction makes infracturing difficult and inadvisable Out-fracturing is the procedure to be chosen

If, to complete an osleotomy, a chisel is used to fracture at the nasion, the surgeon should bear in mind that this technique may cause fractures of the sloping edges of the nasal notch, of the frontal spine, of the perpendicular plate of the ethmoid, destroying the main support of the nasal bridge, and the impact of the chisel may even be transmitted to the cribriform plate, furthermore, when the frontal sinus extends below the fronto-nasal suture line, which is located at the

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*Read at the meeting of the Eastern Section American Laryngological Rhinological and Otological Society Inc. Philadelphia Pa. Jan 9 1958

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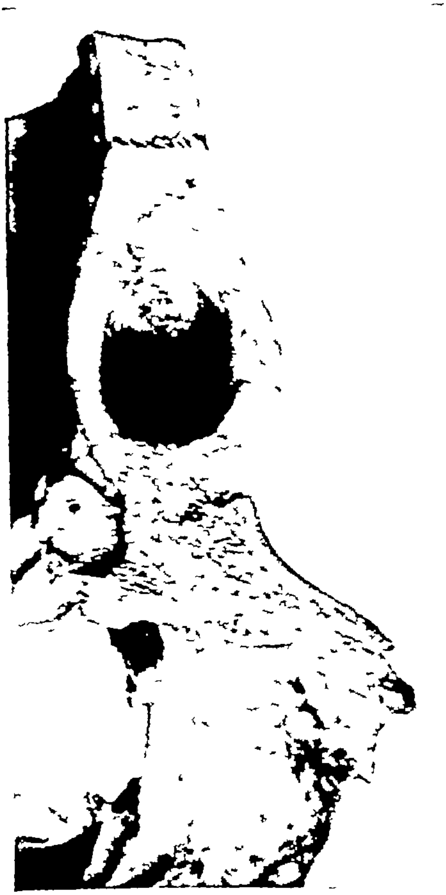


Fig 2 Under-developed frontal sinus The floor of the frontal sinus is about 2 cm above the upper ends of the nasal bones A solid block of bone is found where the sinus is normally located

nasal walls, it turns downward, outward and backward, pointing directly to the inner canthi of the eyes (see Fig 2)

THE PRE-LACRIMAL GROOVE

One of the most important landmarks of the nasal pyramid is the inner rim of the orbit This is essentially the anterior lacrimal crest Adjacent to it, medially, is a groove which is semi-lunar in shape and runs parallel to the inner orbital rim We shall call this groove the pre-lacrimal groove (sul-

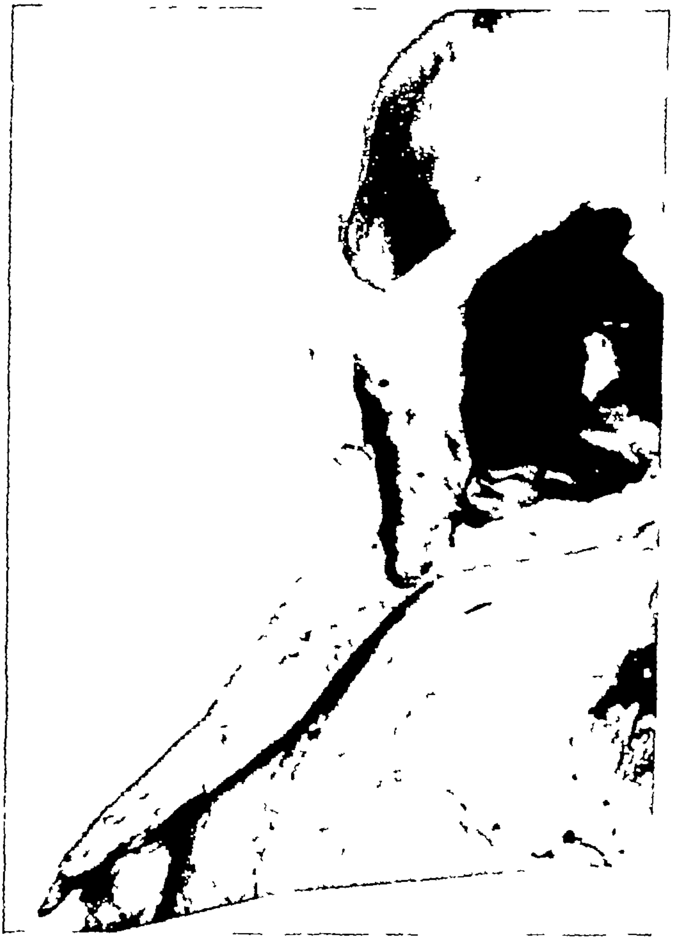
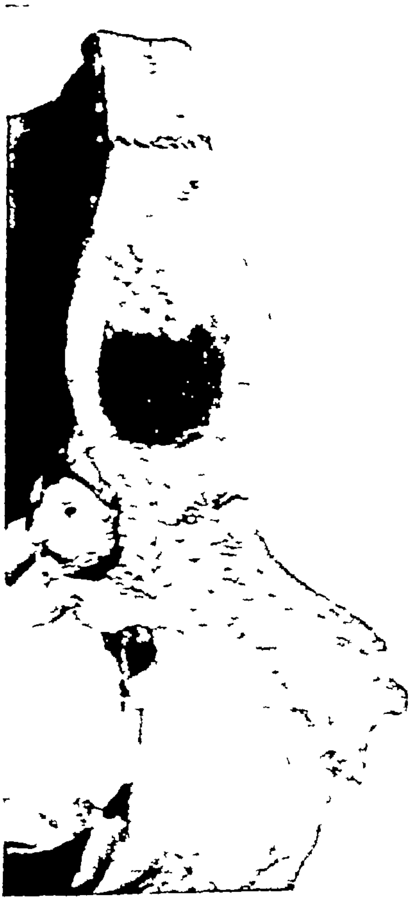


Fig 1 Over-developed frontal sinus The floor of the frontal sinus is about 3 cm below the upper ends of the nasal bones which become part of the anterior wall of the sinus

Before rhinoplastic surgery is considered, X-ray studies of this region should be made These should include the frontal sinus, the nasal bones and the frontal processes of the maxillae The naso-frontal suture line should be mapped out, and its relationship to the frontal sinus and to the above-described block of bone should be determined This suture line originates at the nasion, where it runs straight across the upper limits of the nasal dorsum and, when it reaches the lateral



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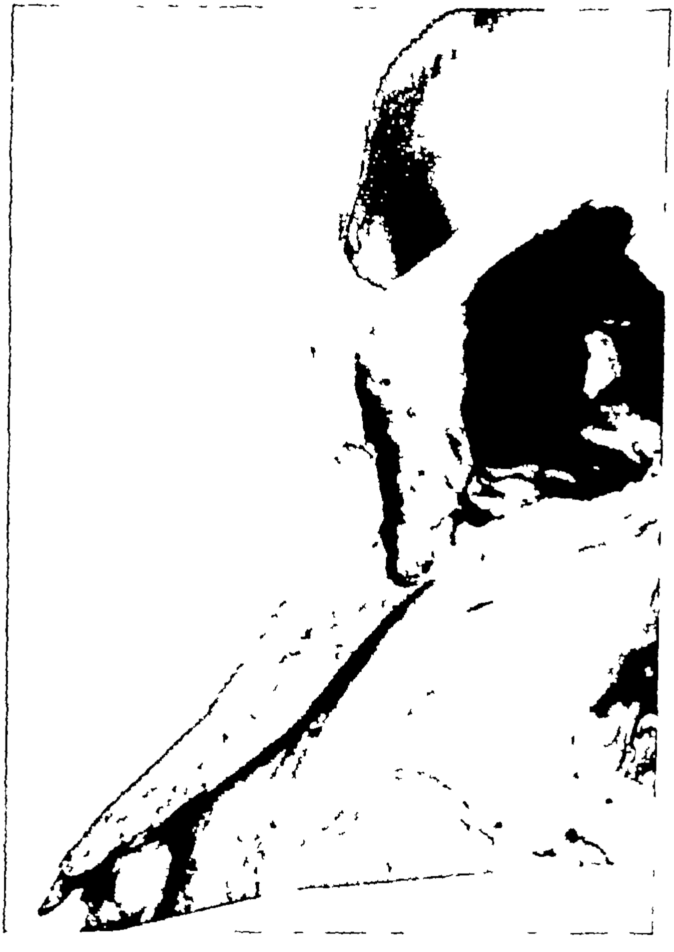

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THE USE OF ANTIBIOTIC-STERIOD COMBINATIONS AS NEBULIZING AGENTS IN THE TREATMENT OF LARYNGEAL CONDITIONS

A Preliminary Report *

BERNARD L SILVERBLATT, M D ,

Pittsburgh, Pa

The treatment of disease entities affecting the larynx is predominantly surgical Except for antibiotics in the acute infectious reactions and streptomycin in tuberculous laryngitis, other therapeutic measures have failed to produce the enthusiastic results portrayed by their author Thus podophyllin, hormonal agents as theelin, adrenalin, etc , are seldom prescribed today Limitations of vocal abuse, smoking and alcohol, persist as standard directives to the patient with hoarseness

For almost two years, we have been using antibiotic steriod combinations in the treatment of many of our laryngeal problems This combination has been used in nebulization form, both as a primary therapeutic agent and as an adjunct to surgical procedures We feel that the combination has rational and merit for usage I would stress, however, that they are not "cure-alls "

ANALYSIS OF THE PROBLEM AND RATIONAL OF THERAPY

Standard textbooks list[1] better than 50 specific diseases of the larynx Standard nomenclature increases this to better than 150 diagnoses This discrepancy is partially due to our own inadequacies in standardizing nomenclature for disease entities, thus a clinical entity may be diagnosed on the basis of the etiology, the pathologic picture, the anatomic deformity or disability, and with the name of an author

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cus pre-lacrimalis) This landmark is important, because it indicates the posterior limits of rhinoplastic surgery

Posterior to this groove are found the following vital structures the lacrimal sac, the naso-lacrimal duct, the orbital contents, the agger nasi cells, the middle turbinate, the cribriform plate and the naso-frontal duct

SUMMARY

1 The frontal sinus may be over-developed and extend downwards beyond the glabella, past the fronto-nasal suture line, reaching as far down as the middle of the nasal bones The nasal bones themselves will then become part of the anterior wall of the frontal sinus, and the floor of the sinus will be attached directly to the inner surfaces of the nasal bones

2 The frontal sinus may be under-developed and stop short of the glabella In this instance, a solid block of compact bone will be found where the sinus is normally located X-ray studies will determine the relationship of the frontal sinus to the nasal bones

3 The nasal notch of the frontal bone is beveled, at the expense of the outer layer, to form a suitable bed for the imbrication of the upper edges of the nasal bones and of the frontal processes of the maxillae The frontal spine extends further downward from the center of the nasal notch, to become fused with the septal crests of the nasal bones and with the bony septum, to give the nasal bridge greater support This construction makes infracturing impracticable

4 The pre-lacrimal groove (sulcus pre-lacrimal) is one of the most important landmarks of the nasal pyramid It is located between the inner orbital rim and the postero-lateral margin of the nasal pyramid It runs parallel to the inner orbital rim, and it is semi-lunar in shape It can easily be felt by digitation This groove indicates the posterior limits for rhinoplastic surgery There are no vital structures anterior to this groove, they are all posterior to it

2054 Locust Street

CLINICAL RESULTS

Antibiotic-steroid nebulization has been utilized in the clinical management of all of these conditions The antibiotic to combat the infectious factor in the etiology of many of these conditions, or the secondary infection that may co-exist, the steroids to act as the blocking or anti-inflammatory agent for the stereotyped reaction that occurs in response to nonspecific irritation In its action it also controls fibrosis of healing

ACUTE LARYNGITIS

Case 1 Young male employed in recapping automobile tires developed hoarseness when the overhead ventilator broke down and he was subjected to the inhalation of concentrated chemical irritants, symptoms had persisted for one week Examination revealed a diffuse redness of the larynx with edema of the mucosa Nebulization therapy was recommended Report of the referring laryngologist 48 hours after therapy was "improved voice with marked clearing of the local reaction'

ACUTE LARYNGITIS

Case 2 Young male railroader was seen in consultation because of hoarseness and painful difficult swallowing, four weeks prior he had been injured and exposed to chemical fumes when a Diesel engine exploded Treatment during his two weeks of hospitalization consisted of penicillin and confinement in an oxygen tent, at this time the mucosa of the hypopharynx and larynx was red and edematous there were residual areas of ecchymosis and ulceration in the nasopharynx One week after nebulization therapy was started the voice had improved and pain and difficulty in swallowing had subsided In another week all symptoms had subsided and the physical findings had returned to normal

Both cases represent specific therapy for a reversible process

The contact ulcer has usually been a chronic difficult problem to treat

Case 1 Music teacher with hoarseness for two weeks failed to show improvement under a regime of therapy prescribed by her home town laryngologist Examination of the larynx showed a diffuse edematous ulceration with exudate on the right vocal cord and a concave ulceration of the right arytenoid One week after nebulization there was 75 per cent improvement the edema and exudate had subsided leaving only the concave ulceration of the vocal process, this was larger than on the original examination Two weeks later healing was complete, voice rest had not been insisted upon

Case 2 A similar result was obtained in a female patient with hoarseness for two months excessive talking and smoking had been part of an unusually active social program there was a large ulceration of the right vocal process Two weeks after therapy the process was 50 per

If we analyze the laryngeal diseases, however, we find that they can be classified into six categories *1* Congenital Defects, *2* Infections, *3* Toxic, *4* Traumatic, *5* Paralysis, neuromuscular and systemic disturbances, *6* Tumors

Of these, congenital defects and paralysis can be eliminated from this discussion The others may be considered, since they have a common factor in that they represent an inflammatory reaction, using the term inflammatory as a nonspecific reaction to injury whether due to infection, allergy, irritation or trauma The inclusion of tumors depends upon these factors *1* Many of the so-called benign tumors of the larynx are actually non-neoplastic in origin, *2* Malignant tumors are of unknown etiology and steroids, and antibiotics have been used to control neoplastic activity in other parts of the body, *3* Nebulization might be a useful adjunct in the postoperative healing program

The pathologic response to inflammation in the larynx is the same as elsewhere in the body, differing only in the symptomatology of the local anatomy The inflammatory reaction takes place in the subcutaneous connective tissue[2,3] This reaction leads to progressive changes, described from the gross appearance, as redness, edema, hyperplasia, fibrosis or hypertrophic changes with keratosis For simplicity we can diagram this gross pathologic picture and coordinate it with our clinical diagnosis as follows

GROSS APPEARANCE		CLINICAL DIAGNOSIS
Redness ↓ Edema	Reversible	Laryngitis ↓ Contact Ulcer Hyperplasia Polyp ↓ Vocal Nodule Papilloma
Fibrosis ↓ Metaplasia	Irreversible	Pachydermia Hyperkeratosis Leukoplakia Cancer

was started and endoscopic removal performed in February and April There was no recurrences at the last examination in November

HYPERKERATOSIS AND LEUKOPLAKIA

Nebulization has been used both as a primary therapeutic agent and also as a postoperative adjunct in these cases The progress of therapy can be observed in the routine examination of the patient We feel that we have been able to reverse the process in cases with early surface changes, and prevent recurrence in those cases requiring endoscopic removal

TUMORS

Nebulization has been utilized in the postoperative care of patients with carcinoma *in situ* removed under direct laryngoscopy

METHOD OF THERAPY

A No 40 DeVilbiss nebulizer is prescribed for home use by the patient The preparation of choice has been cortisporin This is a suspension of aerosporin, neomysin and hydrocortisone in an aqueous vehicle Therapeutically this formula combats infection due to susceptible organisms, and relieves symptoms caused by an inflammatory process The incidence of tissue sensitivity to the components is low While other preparations may be equally effective, we believe that a suspension offers the advantage of a greater concentration and more prolonged action

The patient is instructed in the method of nebulization and treats herself four times daily with 6 to 8 inhalations at each procedure Therapy is decreased to an "as needed regime," with improvement in symptoms and local findings

SUMMARY

An analysis and rational for the use of cortico-steriod-antibiotics combination in various disease entities of the larynx has been presented The clinical results observed in the treatment of various laryngeal diseases with cortisporin cent improved in spite of continuation of her social activity Because of her apprehension, therapy was continued along with limited voice use One week later the voice and local findings were normal, and there has been no recurrence to date

Case 3 S K, age 42, was a salesman with hoarseness for two years, a laryngoscopy had been performed twice previously for removal of a tumor Our examination revealed the presence of a large pea sized granuloma of the right vocal process A recurrence developed after laryngoscopic removal Nebulization therapy was prescribed The patient was not seen again for three months At this time the voice was good and laryngeal examination revealed complete healing with only a small epithelized nodule at the site of the previous granuloma

LARYNGEAL POLYP

The laryngeal polyp is basically a localized edematous reaction It is referred to by clinicians and pathologists in varying descriptive terminology Nebulization has been used as the primary agent in many cases, with a satisfactory reversal of the process and improvement in the voice In other cases treatment has been used as a postoperative adjunct to prevent irreversible granulation We feel that there have been benefits in both situations

PAPILLOMA

Papilloma has been a problem, especially in children, because of its tendency to recur Improvement with antibiotic therapy has been controversial We feel that the antibiotic steroid combination has served to abort the process when used as a postoperative adjunct

Case 1 R M, age five years, was first seen in 1954 A tracheotomy had been performed at the age of two years, and endoscopic removal of papilloma performed repeatedly Laryngeal findings at this time were described as a diffuse growth of papillomas in the larynx and extending into the upper segment of the trachea During 1954 and 1955 we continued to remove papillomas every three months Nebulization therapy was added to his regime in April, 1955 There was complete arrest of the recurrence, so that in October, 1955, the tracheostomy was closed There was no recurrence at the last examination in September, 1957 Age at this time was seven years

Case 2 A. B, age three years was first examined in 1955 with hoarseness due to a diffuse growth of laryngeal papilloma over both cords Endoscopic removal was performed at three-month intervals until February, 1957 when nebulization therapy was started Papillomas were removed in July, 1957, and there has been no recurrence to date Patient is now five years old

Case 3 J H, age three years had papillomas removed on three occasions prior to our examination in February, 1957 Nebulization therapy

THE ROUTINE BLEEDING AND CLOTTING TIME TESTS THEIR MEDICOLEGAL STATUS *†

RUSSELL FLETCHER, M D ,

San Rafael, Calif

The reason for presenting a paper on this controversial subject is to review briefly the history of the tests and the reasons why these obsolete "screen" tests are so extensively employed The modern diagnosis of hemorrhagic disease leaves no doubt that these tests are not accurate, they are not reliable, and actually they may constitute a danger or a menace to the patient and to the physician by inducing false security if he relies upon these tests alone to determine preoperatively whether or not a patient will bleed

THE HISTORY OF THE BLEEDING AND CLOTTING TIME TESTS

These tests have been done for 40 years Bailey[1] in 1922, and Hunt[2] in 1927, each made surveys of several hundred hospitals in the United States in which a large percentage used the tests routinely They found that most of the hospitals and physicians who had stopped using the tests did so because they were not reliable Hunt stated that it was not necessary to have tests done if a proper history and physical examination had been done Shepeard[3] in 1948, stated that the tests were "a vestigial remnant of yesteryear," and the *Journal of the American Medical Association*,[4] in 1955, commented on his article as follows "There have been numerous reports relating experience from Nose and Throat Departments that show bleeding and clotting time estimates are not practical as tests predicting hemorrhages during and after a tonsillectomy Normal results are not a guarantee of freedom from hemorrhage, and abnormal results have been ob-

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†The blood taken for these tests is taken from a puncture wound of the finger or ear and is not done routinely by venepuncture

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nebulization as a primary agent and as an adjunct to surgery have been reported

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ANNUAL OTOLARYNGOLOGIC ASSEMBLY UNIVERSITY OF ILLINOIS

The University of Illinois College of Medicine Department of Otolaryngology announces its Annual Otolaryngologic Assembly from September 29 through October 5, 1958 The Assembly will consist of an intensive series of lectures and panels concerning advancements in otolaryngology, and evening sessions devoted to surgical anatomy of the head and neck and histopathology of the ear, nose and throat Interested physicians should write direct to the Department of Otolaryngology, 1853 West Polk Street, Chicago 12, Ill information, as well as the fact that practically all physicians concede that the tests are of very little value, why are these tests done in so many hospitals, either optionally on the part of the physicians, or are required by hospital regulations? In a rough survey of the hospitals of the San Francisco Bay area, over 50 per cent of them require these tests preoperatively In Portland, Ore, seven of the eight hospitals have the tests done

REASONS GIVEN FOR CONTINUING THE TESTS

1 An occasional physician "thinks that the tests might be helpful sometime" (rarely is there a physician found who is convinced of this fact) *2* Some physicians believe that having the tests done reassures the patient *3* Many physicians, when asked why they continue the test, answer "why worry or fuss about eliminating the tests which cost the patient such a trivial or paltry sum" ($2 00 in the San Francisco Bay area), and they add, "anyhow, most patients have insurance" Although economics should never be a consideration in this problem, it is one of the chief arguments of the proponents for continuing the tests A few facts might be brought out regarding this If it is not reliable and not necessary, it is wasteful, no matter how cheap it is or who pays for it

In Marin County, with a population of 30,000, the three hospitals in this county did 5,446 operations in 1957 At $2 00 per test, this amounts to $10,892 As Marin County is approximately 1 per cent of the State of California, this total would be $1,089,200 for the State If this amount is wasted by requiring an unnecessary test, it is not trivial or paltry One of the health insurance companies in California that does 10 per cent of the health insurance in this State, handles about 90,000 operations per year, therefore, it is self-evident that elimination of such unnecessary tests would be a material saving to all insurance companies *4* The tests have been done for so many years that physicians are hesitant to discard "such time-honored tests," which is chiefly due to inertia The fact that any test has been done routinely by a large number of physicians in any community was a strong medico-served without subsequent bleeding Dependence upon bleeding and clotting time tends to lead to a false sense of security The history and physical examination are much more important, *and if such an examination suggests a bleeding* tendency, then a thorough study is indicated "

There are some statements in the literature, and in text books, which claim in the same sentence that "although the tests are not reliable, their omission "might have disturbing medicolegal consequences" Some text books have stated that the tests were of value in anticipating hemorrhage pre-operatively (These indefinite statements and inferences in the literature, are the points that a lawyer grasps in order to convince a jury that one was negligent if the tests were not done) This is illustrated by our experience in Marin County this past year The surgeons voted unanimously to eliminate the tests pre-operatively, however, the pathologists, who direct all the hospital laboratories, strongly argued that, although they "conceded that the tests are of somewhat limited value," they felt that such statements and inferences as noted above in the literature were of sufficient value for the lawyer to accuse and perhaps convince a jury that there was negligence if the tests had not been done on a patient that subsequently hemorrhaged The result was that the hospital made it obligatory to have the tests done pre-operatively on every patient

The following are a few of the outstanding hospitals and clinics that do not have tests done pre-operatively the Massachusetts Eye and Ear Infirmary, the Children's Hospital in Boston, the hospitals in Baltimore, the University of Michigan Hospital, the Mayo Clinic, the University Hospital in Iowa City, and Stanford Hospital in San Francisco All of these hospitals had routinely used the tests for years, but abandoned them because they were not reliable

In a letter from the legal department of the American Medical Association,[5] dated Dec 13, 1957, it was stated that they knew of no court decision based upon the use or non-use of these tests

Why are These Tests Still Continued? In spite of the above all in-patients about to undergo surgery is a sensible one, and that it should not be changed *unless substantial medical evidence is available* as to the *unreliability* and *futility* of *the tests",* therefore, it is up to the medical profession to show "substantial medical evidence as to the unreliability and futility of the tests"

This evidence is available from three national authorities on hemorrhagic diseases *1* The most concise and graphic presentation of this evidence is given in a letter from Louis K Diamond, M D ,[c] who is Associate Professor of Pediatrics at Harvard Medical School, and who is in charge of the Blood Clotting Laboratory at Children's Hospital in Boston He made the following brief survey *Survey of children referred to the Blood Clotting Laboratory of Children's Hospital of Boston in the past four years*

Group I Patients who had had a routine pre-T and A bleeding and clotting time determination in a hospital laboratory where one or both tests were found to be prolonged beyond normal limits and, therefore, were referred to us for more elaborate tests which we found to be entirely normal, nine patients, most of whom later had T and A without any bleeding disturbance

Group II Patients who had a definite history of bruising in the past and when explored, frequently a history of bleeding in relatives, but normal bleeding and clotting times had been determined by routine methods, 14 patients, nine of whom had hemophilia of varying degrees and five Christmas disease

Group III Patients who bled following surgery, in whom a routine bleeding and clotting time was said to be normal, five patients, of whom four had hemophilia and one Christmas disease

Group IV Patients who bled following surgery in whom a good bleeding and clotting time test, even using venous blood, and supervised by our own laboratory, showed normal values, and yet following T and A in seven cases and dental extraction in one case, there was moderate to severe hemorrhage In two cases blood loss was sufficient to require transfusion legal argument for continuing the test This point is very well covered in the next paragraph, under *"Medicolegal Status"*

5 *The Mediolegal Status* The chief reason why physicians and hospitals have continued this routine pre-operative test is the medicolegal threat or intimidation that failure to have had the tests done might be grounds for negligence if a lawsuit were instigated because a patient hemorrhaged On the Pacific Coast we are particularly aware of malpractice suits This is reflected in the high rates for malpractice insurance The rates given by the American Academy of Ophthalmology and Otolaryngology shows that Oregon has the highest rate in the nation, which is about twice as high as California, and Washington which, in turn, are three times as high as the rates in Texas, Pennsylvania or New Hampshire, and twice as high as New York

What is the accepted or customary practice in the community in which you practice? A letter from the legal department of the American Medical Association to me,[5] dated Dec 13, 1957, outlines the requirements very well and states in part, as follows "To comply with legal requirements, a physician must meet the standards of good medical practice in any service he furnishes a patient These standards are based on what other reputable physicians in the community, or in similar communities, would or would not do in the care of similar cases One of the tests applied, so far as the use of a particular medical or surgical technique is concerned, is the *general reliability and acceptance of such technique* If the value of a particular technique is of such a degree that a substantial number of reputable physicians in the community would utilize it in a given situation, then the failure of a physician to utilize it in the same or similar situation would be a difficult factor to explain in a subsequent malpractice suit It may not constitute negligence *per se*, but the jury would certainly regard such factor with respect Whether or not bleeding and clotting time tests enjoy the degree of acceptability described above, I cannot say *That must be decided by the medical profession* I believe a hospital regulation urging routine bleeding and clotting time tests on all in-patients about to undergo surgery is a sensible one, and that it should not be changed *unless substantial medical evidence is available* as to the *unreliability* and *futility* of *the tests"*, therefore, it is up to the medical profession to show "substantial medical evidence as to the unreliability and futility of the tests"

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He further states "On patients whose history or physical examination indicates a bleeding tendency, then special hemorrhagic tests *by experts* are indicated" He stated that "a surgeon would not be considered negligent if he did not perform routine pre-operative tests for bleeding and clotting time" He also states "in the past, the finger tip method was an accepted and standard practice and afforded the surgeon, the laboratory director, and the hospital administration a degree of medicolegal protection which comes from the performance of the usual and customary procedures Such procedures will not, in the light of present knowledge, continue to be accepted" There are so many interesting and pertinent facts in this article by Dr Diggs, that it would take too long to review them in this paper It is, therefore, strongly recommended that everyone read this excellent article by Dr Diggs

CONCLUSIONS

1 The routine bleeding and clotting time tests are not reliable, authorative medical evidence is herewith presented (It has also been the experience of many clinicians)

2 The tests are dangerous and a menace to the patient and to the physician by inducing a false sense of security

3 The safest practice for the patient, as well as the physician, is to take a careful history of bleeding in the patient and the family, and to make a good physical examination If these show any bleeding tendency, then special hemorrhagic studies *by an expert* are indicated

a A physician with such a patient will not be guilty of negligence if the routine tests were not done pre-operatively and the patient subsequently bled

b A physician with such a patient who relied on the routine bleeding and clotting tests *alone* and did not have special

2 The second authoritative evidence is given by Paul Aggeler, M D,[7] Associate Clinical Professor of Medicine at University of California Medical School, and Head of the Blood Clotting Research Laboratory at Children's Hospital in San Francisco He states that "numerous cases falling into all four categories listed by Dr Diamond have been extensively investigated in his laboratory During the past three years alone, 28 patients whose bleeding and venous blood clotting time were normal, were nevertheless proven by more detailed methods to suffer from well defined clotting disorders (hemophilia, P T C deficiency, P T A deficiency, hypoproconvertinemia and fibrinogenopenia) In about one-third of these patients tooth extraction, tonsillectomy, and even major surgery had been performed, with hemorrhagic complications in every instance In several cases, because of the false assurance afforded by normal bleeding and clotting times, the operation had been done without further investigation, despite the surgeon's complete awareness of the bleeding history In 20 years' experience in this field Dr Aggeler can recall not a single instance in which a bona fide hemorrhagic disorder was discovered solely by the use of routine pre-operative bleeding and clotting times He has seen many cases, however, where false positive results have lead to still further useless and expensive investigations"

3 The third source of evidence that these tests are not reliable, is the article "Diagnosis of Hemorrhagic Diseases—Evaluation of Procedures" Part I appears in the December, 1957, *California Medicine,* and Part II in the January, 1958, issue by L W Diggs, M D, who is Professor of Medicine at the University of Tennessee College of Medicine, and Director of Department of Medical Laboratories, University of Tennessee, City of Memphis Hospitals, who was the guest speaker at the California Medical Association meeting in May, 1957, in Los Angeles This paper discusses in detail the importance of a careful history and physical examination, and states that "they are more reliable than laboratory tests for the prediction of the tendency to bleed at the time of surgical operation, and failure to obtain a history of bleeding episodes may be catastrophic" He also states that "Routine pre-operative

THE TREATMENT OF POLYPOID LARYNGITIS *†

GERSON LOWENTHAL, M D ,

Cincinnati, Ohio

The term polypoid laryngitis designates a localized or diffuse non-specific inflammatory tumor of one or both vocal cords, involving the epithelium and the subepithelial space of Reinke This space is a very thin layer of loose connective tissue between the epithelium and the elastic and muscular tissue of the vocal cords [1] It extends from near the anterior commissure to the vocal process of the arytenoid and to the stria arcuata, superior and inferior,[2] which is the transition point between the squamous and the columnar epithelium above and below It has a scarce arterial supply but a rich venous plexus The epithelium is much thinner, only two or three layers, at the free edge and upper surface of the cord, while there are 10 to 20 layers of stratified squamous epithelium over the remainder of the cord [3] This explains why the inflammatory lesions may be restricted to this space, and why they occur most commonly along the phonating edge and upper surface of the cord

The most common inciting factors for polypoid laryngitis are considered to be the trauma of vocal abuse[4] or the irritation produced by smoking [5,6] These lesions nearly always produce hoarseness, tiring of the voice, occasionally pain or discomfort in the throat, and rarely, respiratory embarrassment Psychologically there is usually apprehension on the part of the patient over the implications of the symptoms

Clinically, the lesions may be placed in two groups localized and diffuse Either of these may be acute, due to sudden vocal strain, or chronic, due to repeated trauma to an unresolved process In the localized, the tumor may be a pedun-

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*Read at the meeting of the Middle Section American Laryngological Rhinological and Otological Society Inc Chicago Ill January 13-14 1958

†From the Departments of Otolaryngology The Jewish Hospital and The College of Medicine University of Cincinnati Cincinnati Ohio

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hemorrhagic tests by an expert, might be accused of negligence

4 Since the tests have been proven to be so unreliable, they should not be required pre-operatively on surgical patients

5 "If it is medically sound, it will stand up legally!"[9]

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POST GRADUATE COURSE
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The next postgraduate course in Laryngology and Broncho-esophagology to be given by the University of Illinois College of Medicine is scheduled for the period October 27 through November 8, 1958, under the direction of Dr Paul H Holinger

Interested registrants please write to Department of Otolaryngology, University of Illinois College of Medicine, 1853 West Polk Street, Chicago 12, Illinois

neoplasm, benign or malignant, not only in gross appearance but also in mode of onset and in production of symptoms" They feel that with few exceptions all benign tumors should be removed

Although the definition, clinical appearance, etiology, histopathology and location may be variable or controversial,

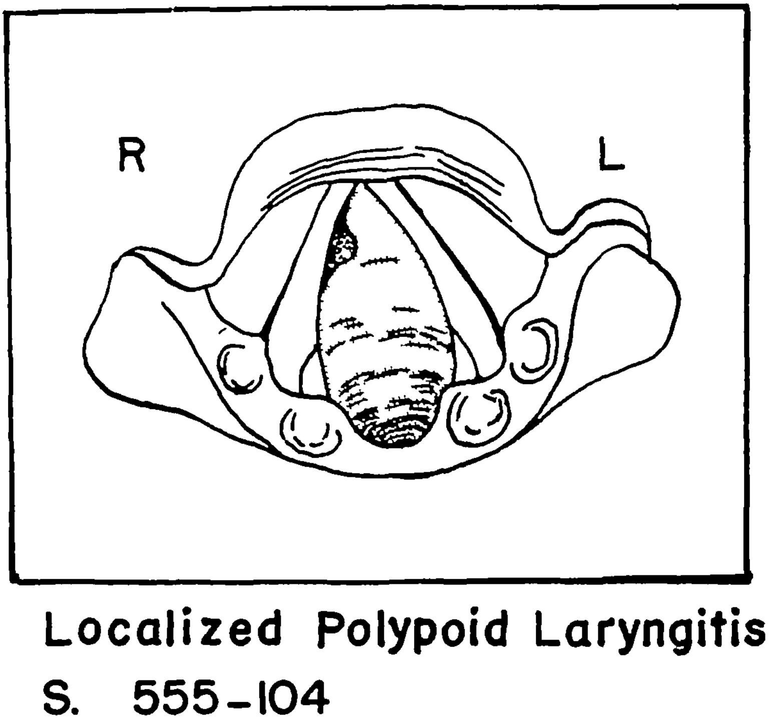

Fig 2 Most common location on cord—the anterior half (View by indirect laryngoscopy)

there is relative unanimity with regard to treatment This paper will concern itself primarily with the surgical treatment

Treatment is divided into three phases first, the medical or "expectant" phase A careful survey of the mouth, ears, nose and throat, and a thorough medical examination to rule culated or sessile mass arising from the free edge or upper surface of the cord, near the junction of the anterior and middle thirds, rarely in the posterior third Occasionally the lesion may be found in the anterior commissure, and infrequently in the posterior commissure It may vary in color from a pale glistening gray to a pink, yellow or purple In consistency it may vary from soft, almost gelatinous, to rather firm and nodular In the diffuse, the swelling involves the anterior half or two-thirds or more of one or both cords The color may vary from a pearly gray to a dusky pink This type may also be flabby or somewhat firm

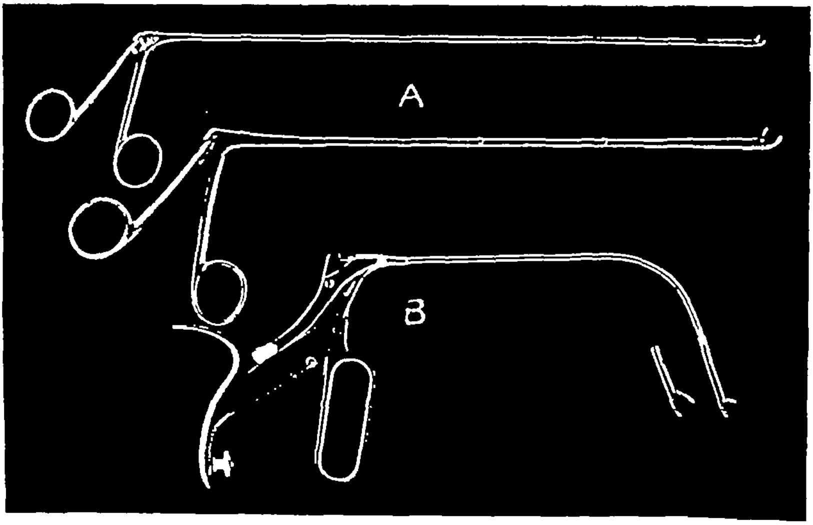

Fig 1 Instruments used in surgical treatment of polypoid laryngitis A Jackson Laryngeal Cup Bite Forceps Angular Jaw 2-4 mm (Direct Laryngoscopy) B Curved Laryngeal Forceps (Universal Handle) 3-4 mm (Indirect Laryngoscopy)

Histologically, the localized and the diffuse lesions frequently cannot be differentiated and show varying degrees of congestion, edema, thrombosis and hyalinization, described by Friedberg and Segall[3] (see Fig 4)

New and Erich,[2] in their monumental paper on benign tumors of the larynx, state that "Inflammatory tumors may bear an exact similarity to almost any type of laryngeal

Chlorophenol If the lesion is reversible within a few weeks, no further treatment may be necessary

The second phase is surgical treatment, which is essentially an excisional biopsy (see Fig 3), with gentle, precise, superficial removal of the lesion It is well recognized that following this principle without damage to the underlying elastic membrane, there appears to be complete regeneration of the cord with normal appearance and function This has been demonstrated by Jackson, Tucker,[11] Lore,[10] Holinger[12] and others[13] Jackson[15] states that it is better to leave a convex edge of the lesion on the cord, even if this should allow a little of the basal tissue to remain, rather than to remove too much tissue, leaving a concavity If necessary, a secondary procedure can be done In polypoid lesions with a suggestion of hyperkeratosis or leukoplakia, biopsies must be taken from various areas in the larynx and carefully labeled as to the site of origin of each specimen Thus, early or *in situ* carcinoma can be localized[14]

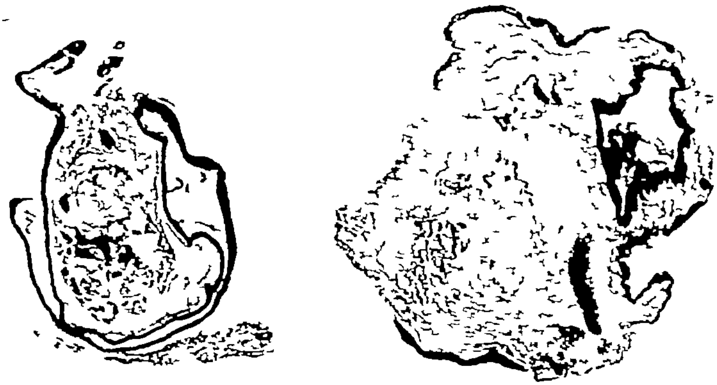

Fig 4 Localized Polypoid Laryngitis Photomicrograph of specimen shown in Fig 3 demonstrating congestion edema thrombosis and hyalinization of the loose subepithelial connective tissue

The recognized methods of surgical removal are by indirect[5] or direct[12] laryngoscopy under local or general anes-

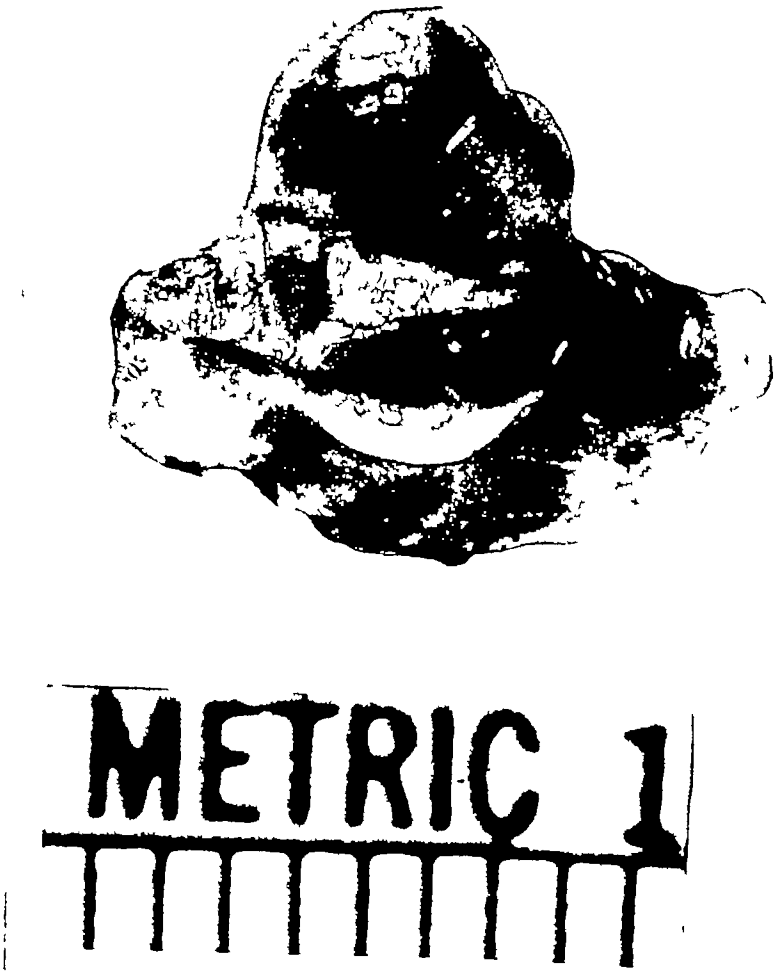

Fig 3 Localized Polypoid Laryngitis Photograph of a lesion removed from position shown in Fig 2

out local or pulmonary, or other systemic disease, is important[8] Elimination of the inciting causes such as vocal abuse, smoking, and alcohol ingestion, are mandatory Voice re-education is required in many cases Specific medical therapy has not been available, although recently steroids have been used by Brodnitz[9] Some symptomatic relief may be obtained from a bland intratracheal instillation such as Mono-P-

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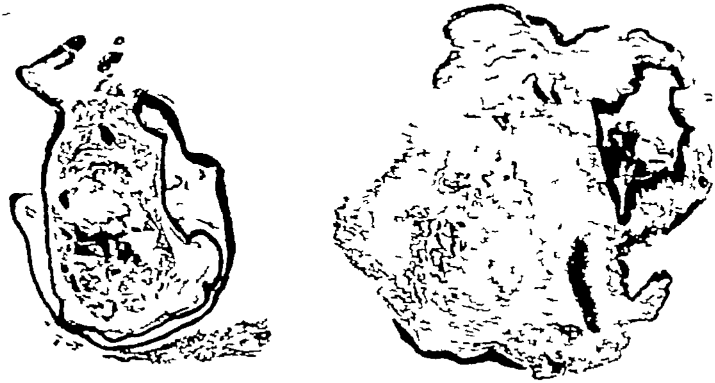

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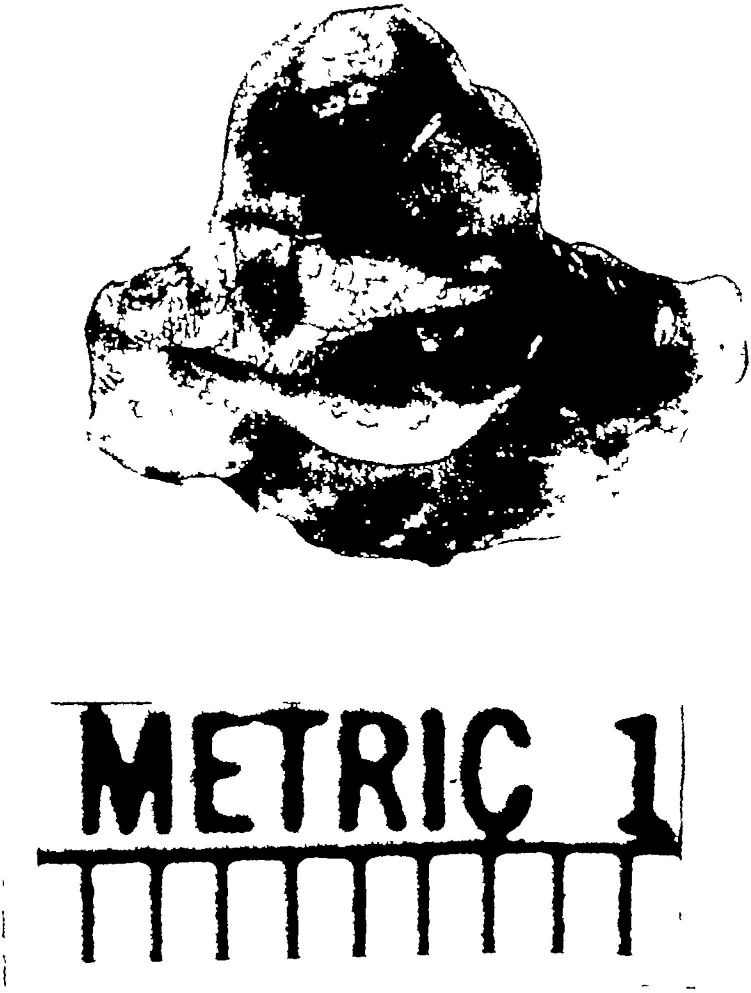

Fig 3 Localized Polypoid Laryngitis Photograph of a lesion remove from position shown in Fig 2

out local or pulmonary, or other systemic disease, is important[6] Elimination of the inciting causes such as vocal abuse, smoking, and alcohol ingestion, are mandatory Voice re-education is required in many cases Specific medical therapy has not been available, although recently steroids have been used by Brodnitz[9] Some symptomatic relief may be obtained from a bland intratracheal instillation such as Mono-P-three-minute intervals, and the patient is encouraged to expectorate the excess Some of the anesthetic is applied to the upper gum to reduce the discomfort of the laryngoscope later

Cocaine hydrochloride, 5 cc of 10 per cent solution, is freshly prepared in the operating room from a measured amount of crystals This is instilled into the laryngopharynx and larynx by the drop method Using a laryngeal syringe with a curved tip, several drops are placed into the valleculae and into each piriform sinus The patient is instructed to breathe quietly while the tongue is being held, after which he expectorates the excess and the procedure is repeated One cc is then instilled over the cords with the patient saying "A" or "E" for a few moments This is also repeated in a few minutes Rarely is more than 3 or 4 cc of the solution required

The combined technique is used most often First, by indirect laryngoscopy the lesion is removed by evulsion with a double cupped biting forceps The patient is usually unaware that this maneuver is different from the instillation of the anesthetic Depending upon the size of the lesion, a large or small tip is used Most, if not all, is removed by this technique

Secondly, a direct laryngoscopy with a Jackson or Holinger anterior commissure laryngoscope, using the Andrews chest support, or more recently, the Lewy[1-] holder, is performed with the patient in the supine position, placing a folded blanket under his shoulders Direct laryngoscopy allows closer inspection of the lesion, and permits trimming of small, loose fargments of mucosa with a small angulated cupped forceps

Multiple and diffuse lesions are removed except when the anterior third of both cords are involved, (see Figs 2, 3, 4), then, the more severely involved side only is operated upon The polypoid cord on the other side is compressed or pinched with-the double cupped forceps in two or three areas to reduce the edema This may be a form of superficial scarification (see Fig 5) It was noted that in a number of patients a subsequent procedure on the second cord was obviated by this thesia, or by suspension[10] laryngoscopy under general anesthesia Rarely, an external approach with tracheotomy may be necessary for removal of a large growth[16] The surgical treatment in the series of cases analyzed was by indirect laryngoscopy, direct laryngoscopy, and most frequently by a combination of the two, under local (topical) anesthesia The operation is simple, orderly, and relatively easy on the patient For a successful procedure it is necessary to secure the cooperation of the patient, and to obtain good anesthesia

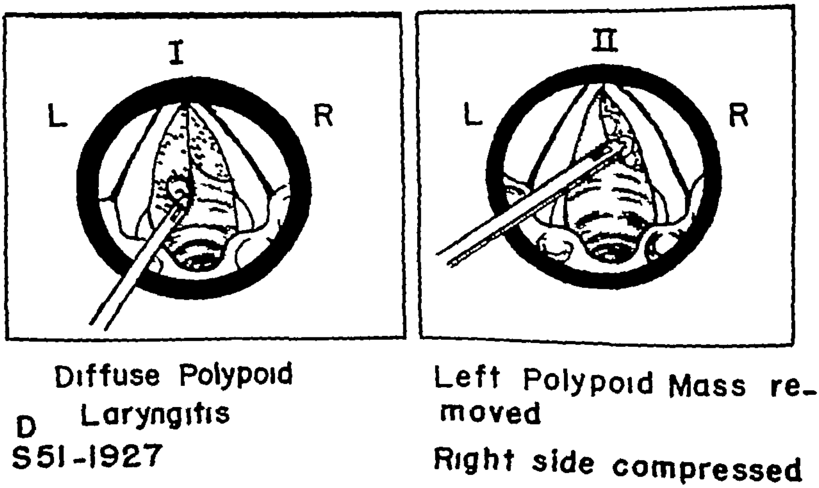

Fig 5 Diffuse Polypoid Laryngitis Bilateral Histologically these lesions are similar to the one shown in Fig 4 I and II—Steps in the surgical treatment (Direct laryngoscopic views)

Since the lesions under discussion occur most frequently in adults, this can usually be accomplished

Premedication consists of seconal or nembutal, grains $\frac{3}{4}$ to grains $1\frac{1}{2}$, taken at bedtime the night before surgery and repeated one hour pre-operatively Morphine sulfate, grains 1/8 to grains 1/6, and scopalomine, grains 1/300 to grains 1/200, are given hypodermically one-half hour pre-operatively

The mouth, oropharynx and hypopharynx are sprayed with 2 per cent pontocaine solution two or three times at about to remove further tissue In one instance there was a recurrence of a lesion on the same cord three years later The second lesion, however, occurred at the junction of the middle and posterior thirds, whereas the original was at the junction of the anterior and middle thirds The lesions also varied somewhat, the first being a polyp and the second a cyst In nine patients with bilateral diffuse polypoid degeneration of both cords, only three required operation on the second side after use of the compression (scarification) technique In one, with only slight diffuse involvement of the second cord, the compression technique was not necessary, and this patient also made a good recovery

SUMMARY AND CONCLUSIONS

1 The particular structure of the subepithelial space of Reinke predisposes to the formation of laryngeal polyps on the vocal cords

2 In the series presented, as in other series, the most common benign tumors are inflammatory, and of these the localized polyps are the most frequent

3 Treatment is divided into three phases the medical or "expectant", the surgical, wherein under local (topical) anesthesia, combined indirect or direct laryngoscopy is performed in all cases, the post-surgical, with removal of the initial predisposing factors and voice correction therapy if required

4 In diffuse polypoid involvement of both cords, the larger lesion is removed The smaller lesion is compressed (superficially scarified) in two or three areas with a double cupped forceps This frequently obviates the need for surgery on the second cord

5 In general, the prognosis in these lesions is good Recurrences are uncommon

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technique *Tschiassny[18] states that scarification is an old treatment and attributes the idea to Hajek Waldapfel[1] reported the use of "simple, superficial scarification of flabby tissue" in such a case, with complete resolution of the lesion without visible scar formation

1940

The third phase is post-surgical This consists of complete vocal rest for a period of 10 to 14 days, followed by a regime of sparing the voice for a period of several weeks and by voice correction therapy, if indicated This phase also includes the removal of the factors which predisposed to the lesion initially At the conclusion of the third phase the cords appear to be well healed and the voice returns to normal Recurrences are uncommon

The case histories reviewed for this paper are of patients over 20 years of age who failed to respond to the medical or "expectant" treatment described in phase one and, therefore, required surgical intervention This group consisted of 62 adult private patients operated upon for benign laryngeal tumors during the past ten years It is interesting to note that even in this small series there was a general distribution of lesions comparable to the vastly larger series reported by New and Erich,[7] and by Holinger[12] Polypoid tumors predominated in the small group, as they did in the larger series Thirty-five of the lesions were polypoid tumors, of which 26 were localized polyps and nine showed diffuse polypoid degeneration of both cords Six were papillary tumors, six were *multiple papillomata*, *there were three* angiomas, one hemangioma, two granulomas, three amyloid tumors, one leukoplakia, two cysts, two thrombosed varices and one vocal nodule In six instances other than the papillomata there were multiple localized lesions, sometimes of different types

In spite of the variation of diagnoses of these benign tumors and of their neoplastic and non-neoplastic character, the treatment of this entire series was essentially the same Following surgery the cords healed well and appeared normal, and the voice returned to normal within a period of several weeks In only two cases was it necessary to go back a second time

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*He suggests that diffuse lesions be known by the descriptive term 'subepithelial chronic edematous corditis

SUBCOMMITTEE ON HEARING IN CHILDREN

The American Academy of Ophthalmology and Otolaryngology, through its Subcommittee on Hearing in Children of the Committee on Conservation of Hearing, has been conducting a long-term nationwide study of problems relating to the conservation of hearing in children The specific aims are to develop the most efficient case-finding methods and to use these methods in estimating the magnitude of the problem in the country, to study state laws and review current practices and facilities for rehabilitation of hearing impaired children, to help develop methods for medical and surgical rehabilitation standards, and ultimately to use the Subcommittee findings in assisting professional workers to improve and enhance programs in hearing loss

In the second year of operations, a full-time Executive Director has been engaged, and offices established at the Graduate School of Public Health, University of Pittsburgh An initial study is being conducted in Pittsburgh to identify early medical signs and symptoms which may indicate danger of hearing impairment, to measure the psychological, social and other effects of such impairment and to develop efficient and economical methods for the testing of hearing in children The Pittsburgh study is a cooperative effort among the following The Subcommittee on Hearing in Children, the Graduate School of Public Health and the School of Medicine of the University of Pittsburgh, the Pittsburgh Board of Public Education, and the Allegheny County Department of Health.

The members of the Subcommittee on Hearing in Children are Dr John E Bordley, Baltimore, Dr Victor Goodhill, Los Angeles, Dr Hollie E McHugh, Montreal, Dr S Richard Silverman, St Louis, and Dr Raymond E Jordan, (Chairman) Pittsburgh An advisory committee of consultants from the University of Pittsburgh includes Dr Samuel M Wishik, Dr Leo G Doerfler, and Dr Isidore Altman Grants from the United States Children's Bureau through the Pennsylvania Department of Health and from the National Institutes of Health are providing financial support

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Meeting Place—Kyoto University, Kyoto, Japan

Friday, September 12th, 1958

8 00 P M -10 00 P M —Reception (Party) Shimomura House in Kyoto

Saturday, September 13th

8 00 A M —Inaugural Session (in Kyoto University Hall)

9 00 A M -12 00 M —First Scientific Session

12 00 M -2 00 P M —Luncheon (Reception The Place not decided)

2 00 P M -6 00 P M —Sightseeing in Kyoto

8 00 P M —Banquet, Miyako Hotel

Sunday, September 14th

8 00 A M -11 30 A M —Second Scientific Session

11 30 A M -12 00 M —Closing Ceremony

12 00 M —Departure for sightseeing in Nara

1 00 P M —Luncheon, Nara Hotel

2 00 P M -6 00 P M —Sightseeing in Nara

7 00 P M —Return to Kyoto

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VOL LXVIII JULY, 1958 No 7

THE MOTOR ACTIVITY OF THE CRICOPHARYNGEUS MUSCLE *†‡**

JOHN A KIRCHNER, M D ,

New Haven, Conn

Of the many muscles involved in the complex act of swallowing, none has equaled the cricopharyngeus in stimulating the curiosity of the investigator, the interest of the clinician and the respect of the esophagoscopist

First mentioned as a distinct anatomical entity by Valsalva[1] in 1717, the cricopharyngeus was recognized by succeeding anatomists,[2,3,4] who usually included it with the inferior constrictor muscle, as its lower-most or cricopharyngeal portion Its sphincter-like action was recognized in 1823 by Home[5] and later discussed by Mikulicz,[6] 1881, Killian,[7] 1908, and Jackson[8] in 1914 Its relation to the mouth of the esophagus was carefully studied by Elze[9] in 1929, and more recently by Lerche [10]

Its physiological identity has been further demonstrated by studies in comparative[11] and gross anatomy,[12] by roentgenographic demonstration of sphincter action,[13,14] and by the relief of post-poliomyelitic dysphagia following surgical section of the cricopharyngeus muscle [15]

Spasm of the cricopharyngeus muscle and its production by

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*Presented as Candidate's Thesis to American Laryngological Rhinological and Otological Society 1957

†From the Otolaryngology Section Department of Surgery Yale University School of Medicine

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**Recipient of the Harris P Mosher Award 1958 autonomic imbalance is frequently mentioned by clinical authors as a cause of dysphagia, but without much experimental evidence to support it. One of the few basic investigations of this problem was reported by Sjoberg in 1939,[16] involving fluoroscopic studies of the barium-filled esophagus in cats after various combinations of cranial nerve sections in the neck. After bilateral vagotomy, autopsy showed a narrowed condition in both the upper and lower ends of the esophagus, attributed by Sjoberg to spastic contractions during life. Administration of ergotamine tartrate to vagotomized cats to combat sympathetic activity produced relaxation at both the cricopharyngeal and cardiac ends of the esophagus. The parasympathetic action was then simulated in these animals by injection of acetyl-choline, whereupon the cricopharyngeus relaxed and peristaltic waves were seen passing down the esophagus. Sjoberg's conclusion from these findings was that the esophageal ostia are caused to contract by the adrenergic sympathetic fibers, while the cholinergic vagus fibers bring about relaxation.

Further support for this interpretation was furnished by Rogers,[17] who reported relief of severe dysphagia in a woman with a spastic cricopharyngeus muscle on whom he performed bilateral extirpation *of the superior cervical sympathetic* ganglia. One must admire his courage as well as his surgical result, for his operation had very little experimental or clinical evidence to recommend it. Even today a sympathetic supply to the cricopharyngeus is flatly denied by Hollinshead,[18] who states that "the cricopharyngeus muscle, being a voluntary one, is *not innervated by the sympathetic system*, and there seems to be no ready explanation as to why a cervical sympathectomy should relieve spasm of this muscle, as it was reported to do by Rogers."

Although the main vagal branches to the cricopharyngeus have been identified,[19] and a sympathetic as well as a parasympathetic component is generally agreed to exist, there is no definite *mention in modern literature* as to what type of activity (contraction or relaxation) is mediated by the vagus or sympathetic branches to the cricopharyngeus.[20, 21, 22] Nor is it even certain that a specific type of activity is mediated exclusively by one or the other autonomic division as shown by studies on the cardiac end of the esophagus Carlson, for example, showed that the vagus carries both motor and inhibitory fibers to the cardia, and that the splanchnics (sympathetic) also carry both motor and inhibitory fibers to this area, the action depending on the state of contraction of the cardia at the time of stimulation[23]

The purpose of my present study, therefore, is to demonstrate, in each case, the effect of stimulation or interruption of the cervical sympathetic or parasympathetic trunks on the motor activity of the cricopharyngeus muscle

Such experimental conditions simulate the autonomic imbalance said to exist in certain cases of spastic dysphagia The resulting increase or decrease in tonus can then be demonstrated by means of a pressure-sensitive recording device placed in the hypopharynx at the cricopharyngeus level

Pharyngeal pressures during deglutition have been studied and recorded by investigators since the late Nineteenth Century In 1880 Falk and Kronecker measured the pharyngeal pressure generated during deglutition in themselves and in dogs They observed the "squirting" action on liquids and semi-solids exerted by the muscles of the mouth and the pharynx by the use of a "T" tube[24] Kronecker and Meltzer in 1883 reported their observations of the swallowing mechanism in dogs, using small balloons to record intraesophageal motility[25] Meltzer considered the squirting action to be the result of pressure exerted by the mylohyoid muscles, because he was able to eliminate it by sectioning the mylohyoid nerves He reported that this operation made the first stage of swallowing impossible, so that the bolus had to be introduced by the operator into the dog's pharynx in order for the animal to swallow[26] This same investigator, in 1907, added further evidence of the importance of the oral musculature in swallowing by cutting the middle and inferior constrictors of the pharynx in the dog, in addition to removing the muscularis of the cervical esophagus A dog, prepared in this fashion, was still able to swallow normally and could drink from a bowl of milk placed below the level of the head, thus eliminating the effect of gravity[27] Cannon and Moser, in 1898, were the first to use fluoroscopy to study esophageal motility in animals These workers also noted the rapid squirting action of fluids from the pharynx to the level of the heart[28]

Although these experiments contributed much to our knowledge of the motor activity of the pharyngeal and oral musculature, the graphic recording of such motor activity was inexact, and the pressure readings unreliable[29] It was not until 1943, with the development of an electronic device by Wetterer,[30] that a practical means of recording intraluminal pressures was made available Wetterer described the principle of using a differential transformer to construct a miniature manometer, a system having excellent recording properties with a minimum of amplification The device was later modified by Gauer and Gienapp[31,32] in 1950 to fit into the end of a No 8 Cournand catheter for the recording of intracardiac and intravascular pressures This instrument was used by Fyke and Code in 1955 for recording pressure changes in the pharyngoesophageal region during deglutition in normal human subjects[33] Their work showed a definite pressure gradient beginning in the pharynx and traveling down through the cricopharyngeus area into the esophagus during the act of swallowing The high pressure in the cricopharyngeus region remained unchanged throughout most of the act of swallowing, and dropped only momentarily when the pressure wave reached this area

The activity of the individual musculature involved in swallowing was later studied by Doty and Bosma by means of electromyography These workers took electromyographic records from 22 muscles likely to participate in deglutition Their work substantiated that of Fyke and Code, showing a downward progressing contraction wave and an inhibition of the inferior constrictor during the entire course of lead muscle activity[34]

PRESENT STUDY

After controls had been established in the normal dog, the action of the cricopharyngeus muscle was studied under the following conditions

1 Unilateral vagus section above the ganglion nodosum

2 Bilateral vagus section above the ganglion nodosum

3 Faradic stimulation of the vagus and cervical sympathetic trunks

4 Faradic stimulation of the cricopharyngeus muscle

5 Surgical section of the cricopharyngeus muscle

The methods used in studying the motor activity of the cricopharyngeus were the following

1 Observation of the dog's ability to swallow his usual food

2 Endoscopic examination of the soft palate, pyriform sinuses and cricopharyngeus sphincter area with the dog under light general anesthesia

3 Fluoroscopic and roentgenographic studies of the hypopharynx with barium mixtures

4 Pressure changes in the hypopharynx at the cricopharyngeus level during deglutition, using an electronic pressure-sensitive pick-up

These methods are standard and seem self-explanatory except for the last, which requires further explanation

In the beginning of this experiment we were using a Gauer-type pressure capsule attached to the proximal end of a 2 mm polyethylene tube introduced through the mouth to the cricopharyngeus level, and recording the motor activity of the cricopharyngeus by means of a Hathaway oscillograph This gave satisfactory and sensitive responses, as shown by Fyke and Code, but seemed to have certain disadvantages First, if a fold of mucosa came to overlie the end opening (or side opening as was later tried) the pressure determination was interfered with, therefore, the open end was enclosed in a small, partially inflated balloon This, however, was soon abandoned because of distortions produced in the balloon by the contracting cricopharyngeus muscle, with resultant inaccuracies in the reproduction of intraluminal pressures

My chief objection, however, to present techniques of recording pressures at the cricopharyngeus level is that this area is pulled upward during swallowing, so that a recording device introduced to the level of the cricopharyngeus sphincter at rest and kept at this level during swallowing is recording pressure not in the cricopharyngeus segment but in the upper cervical esophagus While there is some evidence that a small polyethylene tube will ride up and down with the cricopharyngeus[35] during deglutition, there seemed enough doubt on this point to have warranted the construction of a pressure-recording device which would respond with equal sensitivity along a 3 or 4 cm distance If such a device were of small diameter and of smooth surface it could be introduced into the pharyngo-esophageal junction behind the cricoid cartilage, allowing the cricoid and cricopharyngeus to ride up and down over it, and recording the motor activity of the cricopharyngeus whether it was elevated or at rest

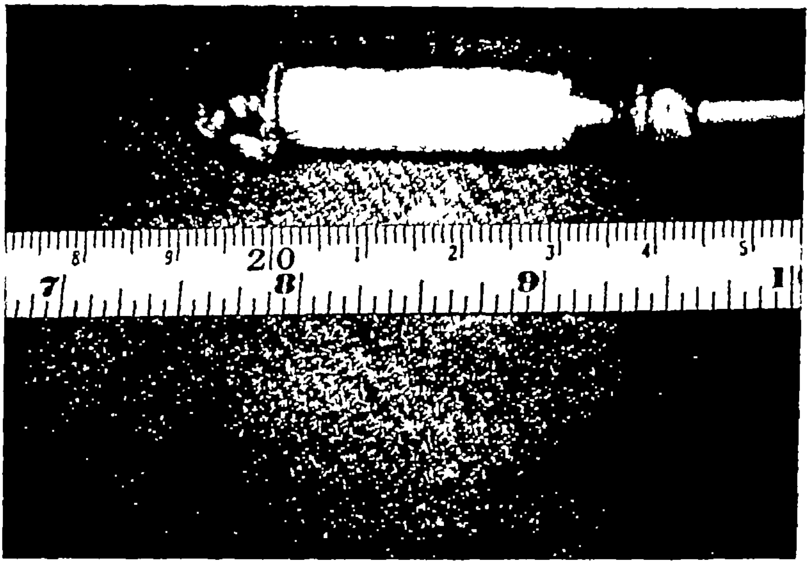

Fig 1 Pressure-sensitive electronic pick-up used in hypopharynx at cricopharyngeus level

For the development of such a recording device I am indebted to Dr Albert Field, Jr , of the Cardiopulmonary section of the Department of Internal Medicine A pressure-sensitive

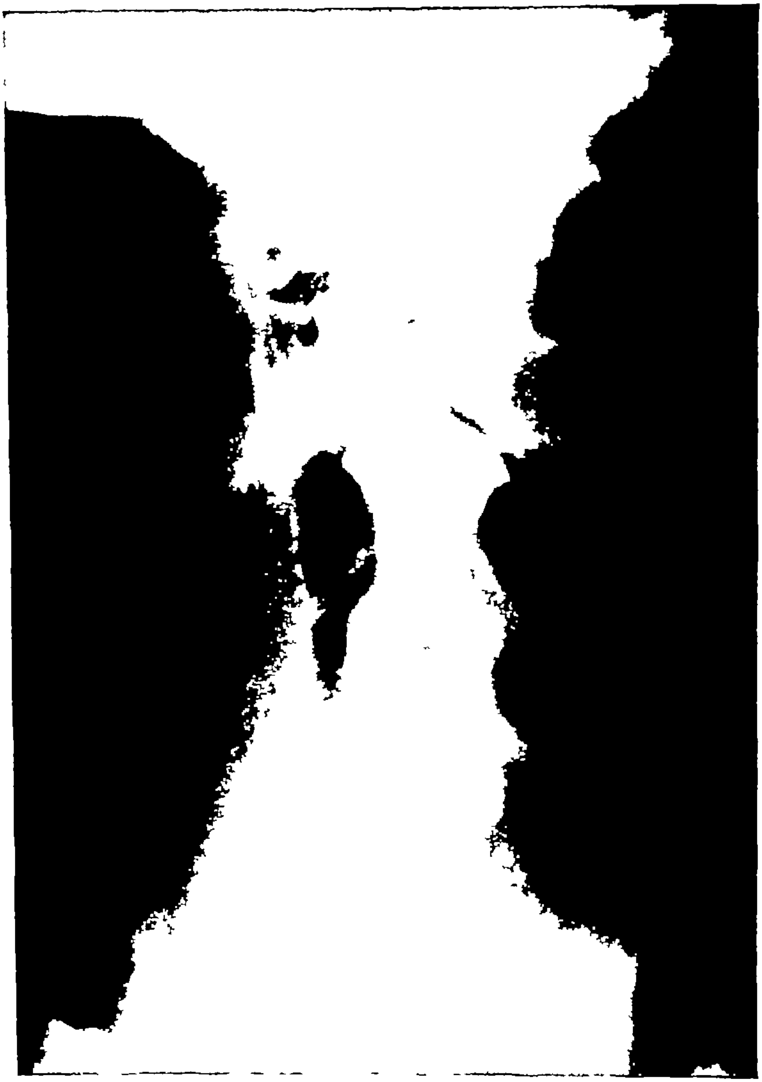

Fig 2 Dog No 1—Normal AP view after barium swallow The trachea deviates to right in supine position in this case but may deviate to left, as seen in other examinations

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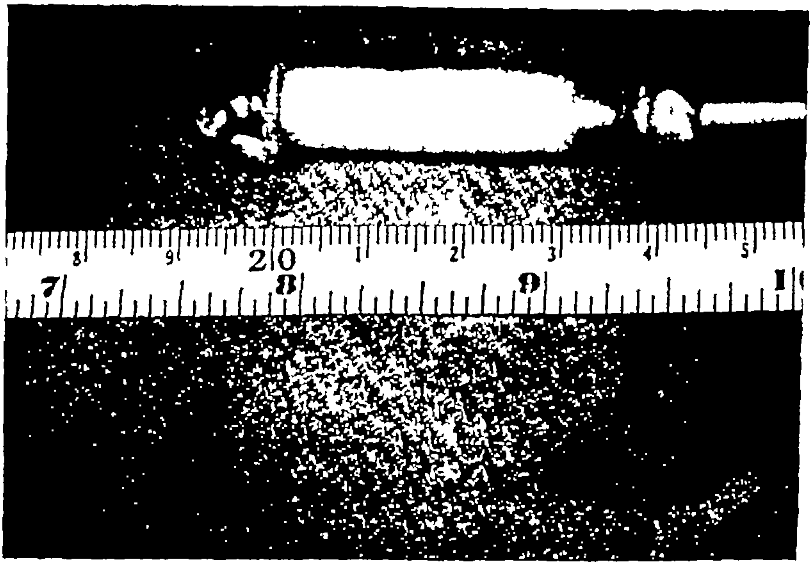

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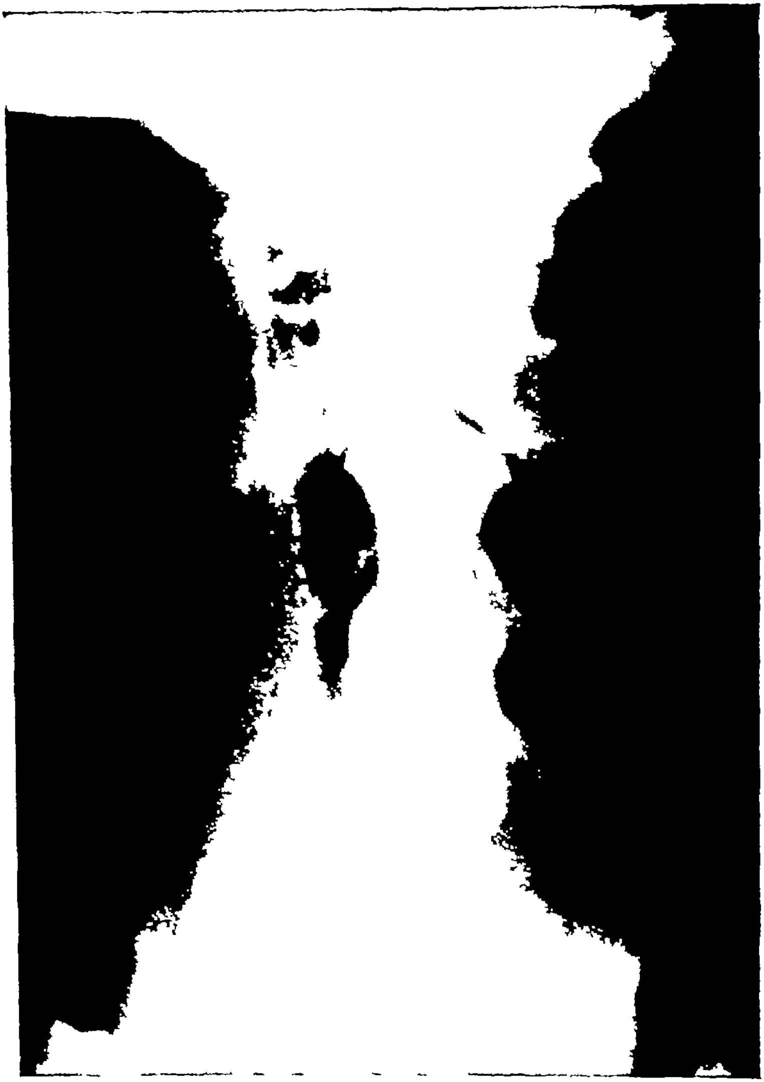

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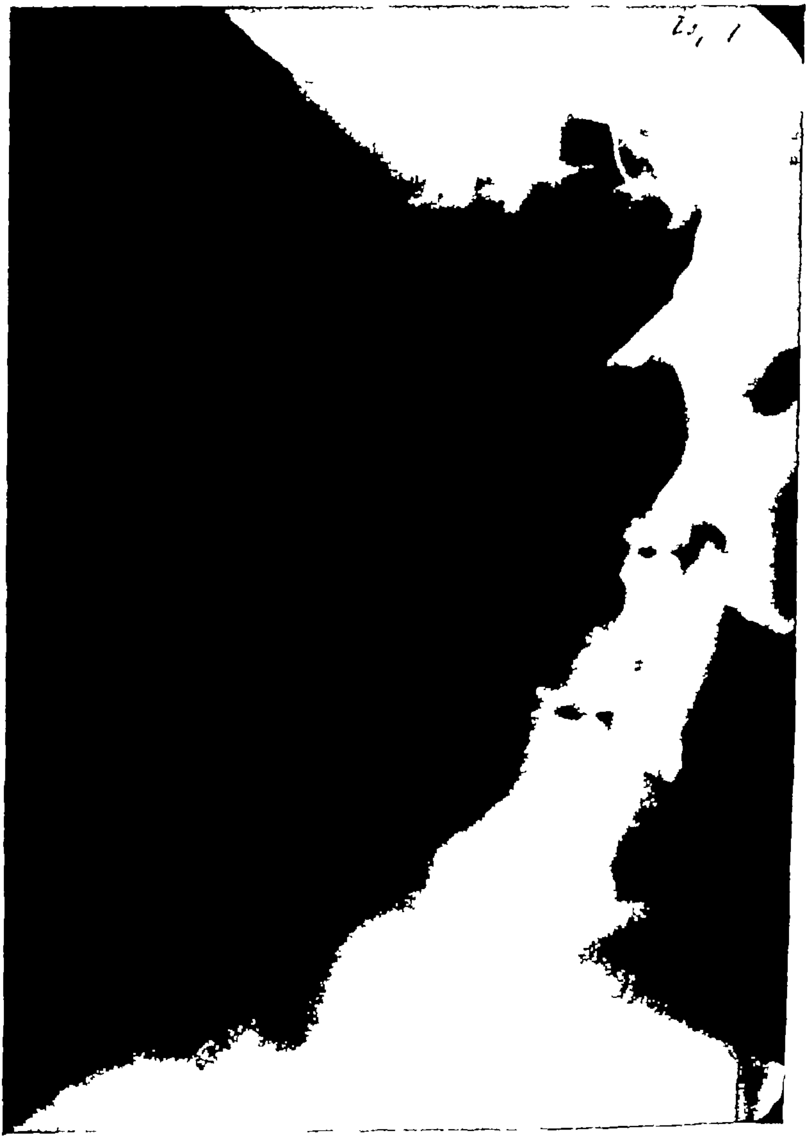

Fig 3 Dog No 1—Normal lateral view after barium swallow A very small amount of barium remains in the valleculae

pick-up was constructed, consisting of a variable capacitance which measures pressure changes by means of variations in a tuned circuit, based on a principle described by Buchtal and Warburg in 1943.[36] It is equally sensitive to pressure at any point along the distance of 3.5 cm., and allows a permanent record to be made by a direct writing electrocardiographic instrument.

The equipment has been checked for performance against a Sanborn pressure capsule and found to be accurate, sensitive

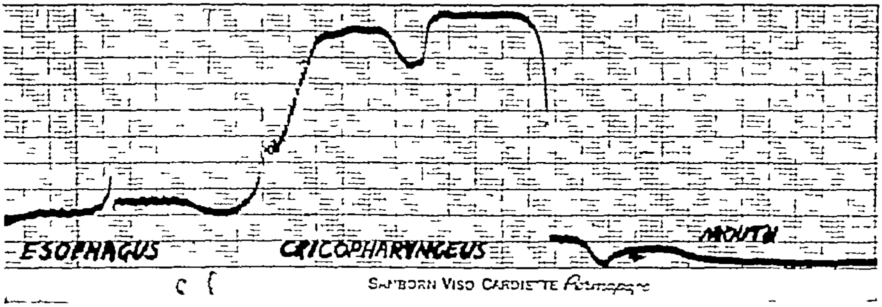

Fig. 4.—High-pressure area encountered at cricopharyngeus as cable is withdrawn from thoracic esophagus.

and brisk in response. Calibrations and other details are described in a separate report.

Because of variations in the base line under different operating conditions, calibrations for exact pressures are not reliable. The calibrations are included, nevertheless, (mm. Hg) to indicate direction of deflections with positive and negative pressure and to indicate approximate pressure ranges. Changes in pressure are, of course, readily demonstrated by the shape of the curves.

NORMAL DOG

Deglutition.—Ate regular diet without difficulty.

Endoscopic Examination.—The soft palate, pharynx, larynx and tongue move normally. A definite annular contraction was seen behind the cricoid cartilage.

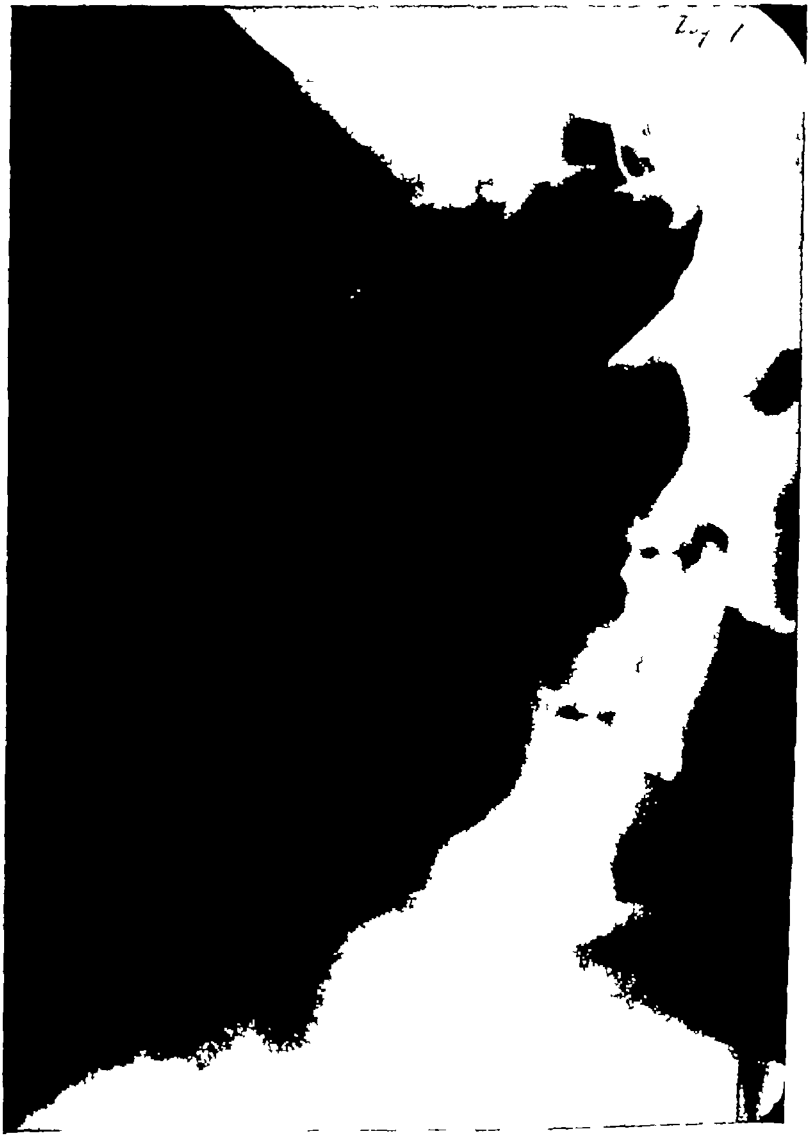

Fig 3 Dog No 1—Normal lateral view after barium swallow A very small amount of barium remains in the valleculae

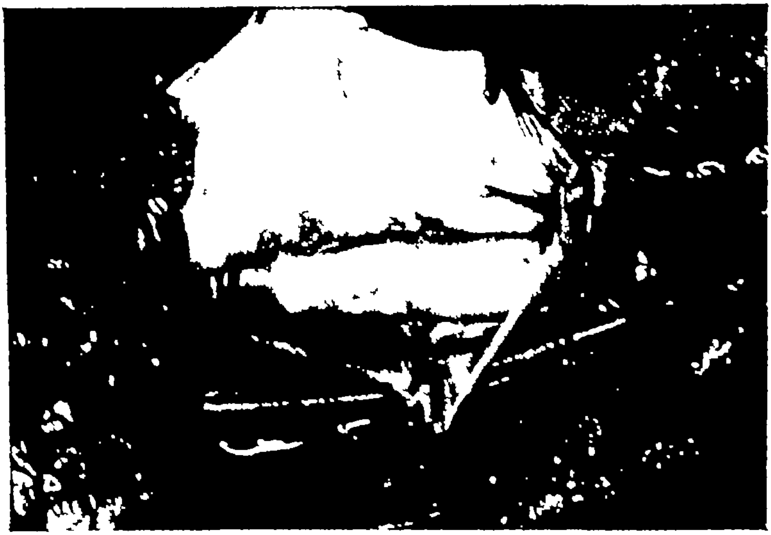

Fig. 6.—Dissected specimen showing pressure pick-up in position at cricopharyngeus level.

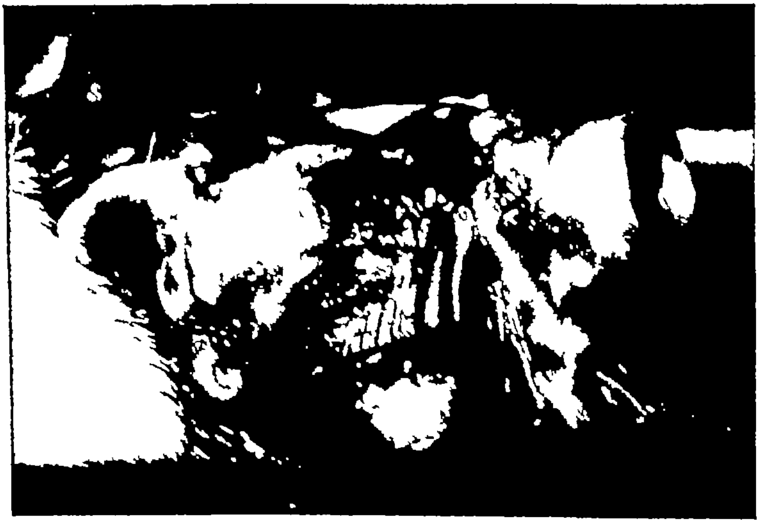

Fig. 7.—Dissected specimen showing cricopharyngeus and thyropharyngeus portions of inferior constrictor muscles. (Operator's finger is in lumen of hypopharynx.)

X-ray Fluoroscopy of a thin barium mixture showed rapid descent of the liquid from the mouth to the level of the heart with no tendency to collect in any of the pharyngeal recesses A normal soft tissue pattern behind the cricoid cartilage was seen on the lateral views (see Figs 2, 3)

Pressure Studies Because of the fact that deep general anesthesia abolishes the swallowing reflex, light nembutal anesthesia was used Pressure readings were made when the deglutition reflex could be stimulated by gently stroking the posterior pharyngeal wall

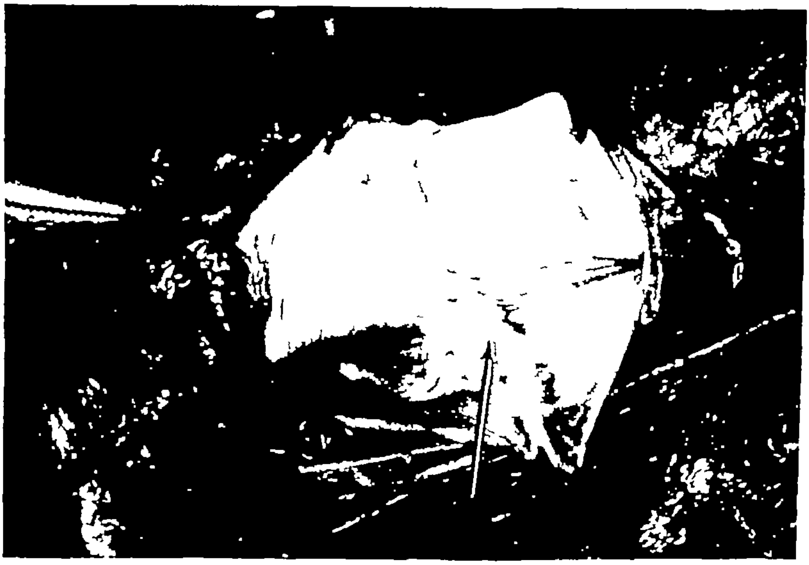

Fig 5 Dissected specimen showing annular fold in hypopharynx behind cricoid cartilage

The pressure capsule was first introduced into the thoracic portion of the esophagus and the recording base line adjusted on the recorder The capsule was then slowly pulled up from the esophagus into the mouth, during which an area of high pressure was encountered in the cricopharyngeal region (see Fig 4) This was a constant finding, whether the dog was in a prone or supine position This high pressure area was found to be 19 5 cm from the upper incisor teeth and corre-

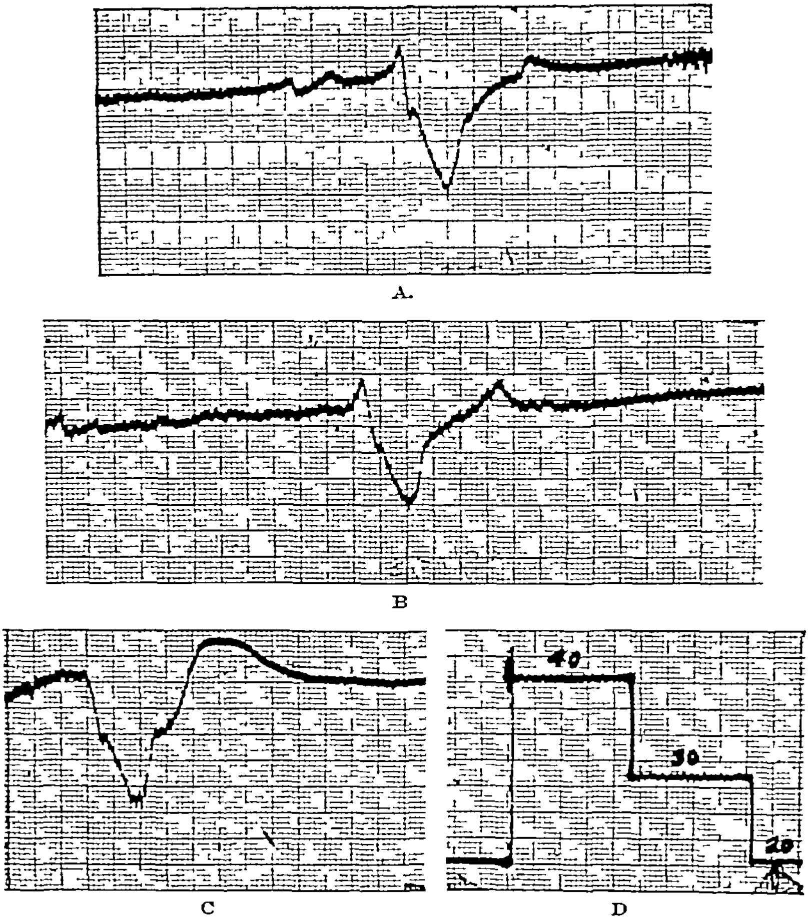

Fig 9 A-B-C—Pressure recordings from cricopharyngeus level during act of swallowing D—Calibration (mm Hg)

nodosum, where it joins the superior cervical sympathetic ganglion The pharyngeal ramus of the vagus, which supplies parasympathetic innervation to the constrictor muscles leaves the vagus trunk cephalic to the ganglion nodosum at its point of emergence from the jugular foramen Whether the sympathetic trunk gives off separate rami to the pharyngeal plexus or to the pharyngeal musculature along its cervical course, as it does in man, I could not determine from the available literature (see Fig 10 for details) sponded almost exactly to the area of annular constriction seen on endoscopic examination (see Fig 5) The mid-point of the recording capsule was introduced to this level for deglutition patterns and other studies in this dog (see Fig 6)

The swallowing patterns shown here illustrate the characteristic curve obtained in all our experimental animals At the beginning of cricopharyngeal activity a small rise in pressure can be seen, probably corresponding to the advancing peristaltic wave Almost immediately the cricopharyngeus undergoes a marked relaxation, followed again by a contraction, which may rise to or above the original base line level (see Fig 9)

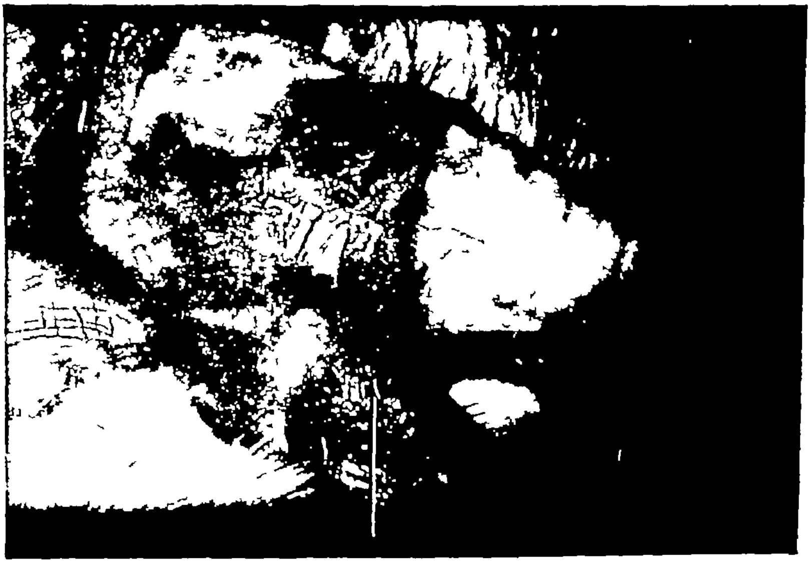

Fig 8 Dissected specimen showing cricopharyngeus portion (arrow) of inferior constrictor separated from thyropharyngeus Pressure determinations were made at cricopharyngeus level

SECTION OF ONE VAGUS NERVE

In the dog the vagus nerve carries with it the sympathetic trunk throughout most of its cervical course The sympathetic joins the vagus opposite the inferior cervical sympathetic ganglion and leaves it again just caudal to the ganglion

X-ray The barium mixture cleared the pharynx easily There was no residual barium in any of the pharyngeal recesses nor were there any changes in the soft tissue patterns (see Figs 12, 13)

Pressure Studies Swallowing patterns show much less relaxation of the cricopharyngeus during swallowing, with a higher positive pressure (see Figs 14, 15)

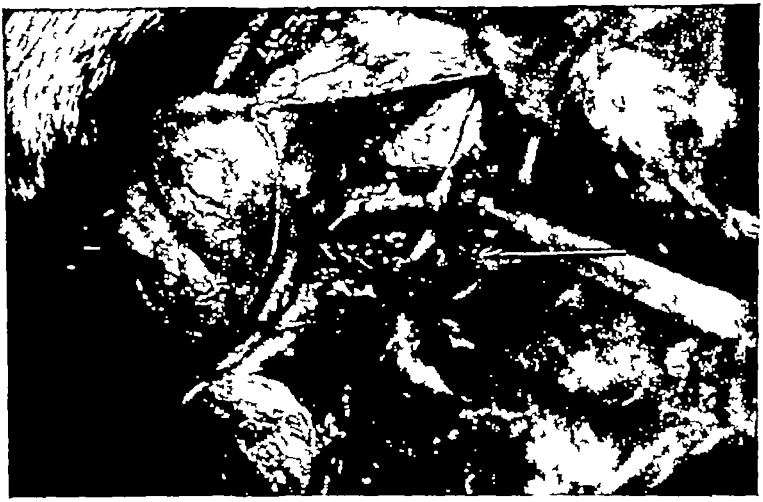

Fig 11 Vagus nerve (arrow) approaching base of skull

DISCUSSION

It is interesting that this dog had no dysphagia, although there was a curtain movement of the pharynx, deviation of the soft palate, and paralysis of the right vocal cord This may be due to the fact that the free portion of the epiglottis of the dog lies above the soft palate, allowing the ingested food and liquids to pass down lateral to the larynx and affording added protection to the laryngeal inlet during the act of swallowing The decreased relaxation of the cricopharyngeus during deglutition following unilateral vagus section may be due to an over-activity of the remaining sympathetic nerve supply I do not believe it is due to a lower starting pressure,

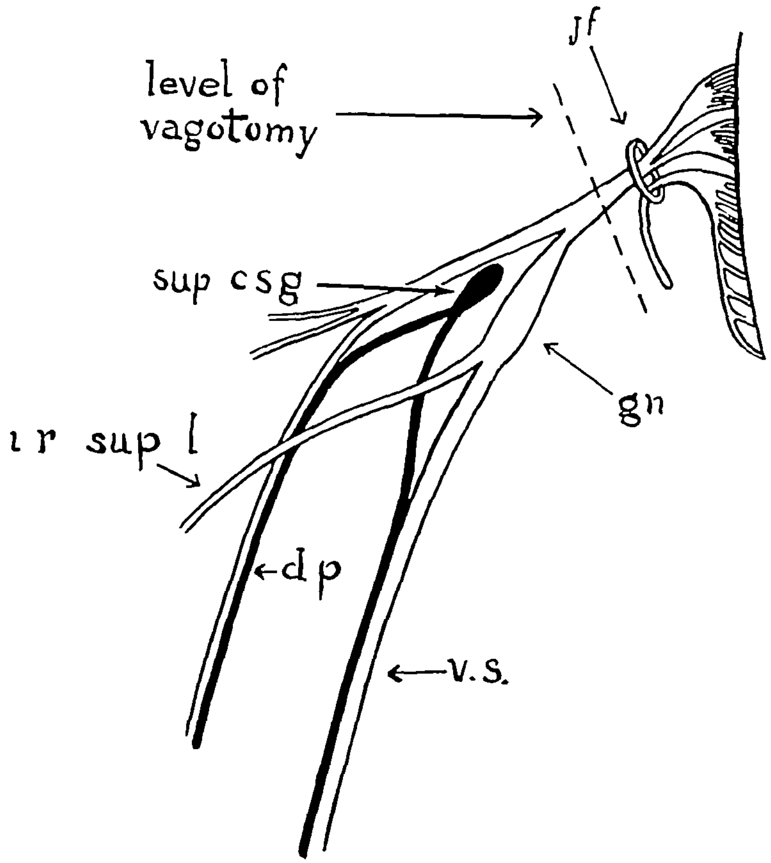

Fig 10 Diagram showing trunks of laryngeal and pharyngeal nerves (from Lemere[19] j f —Jugular foramen g n —Ganglion nodosum v s —Vago-sympathetic trunk d p —descending pharyngeal i r sup l—Internal ramus of superior laryngeal sup c s g —superior cervical sympathetic ganglion Level of vagotomy shown by dotted line

The right vagus nerve was exposed by dividing the muscle which corresponds in the dog to the digastric, then sectioned at its emergence from the base of the skull in order to include the pharyngeal ramus (see Fig 11)

Deglutition The dog continued to eat normally during the entire period of observation of three weeks

Endoscopic Examination The right vocal cord remained motionless in a partially abducted or cadaveric position There was a curtain movement of the pharynx to the left and a deviation of the soft palate to the left

X-ray The barium mixture cleared the pharynx easily There was no residual barium in any of the pharyngeal recesses nor were there any changes in the soft tissue patterns (see Figs 12, 13)

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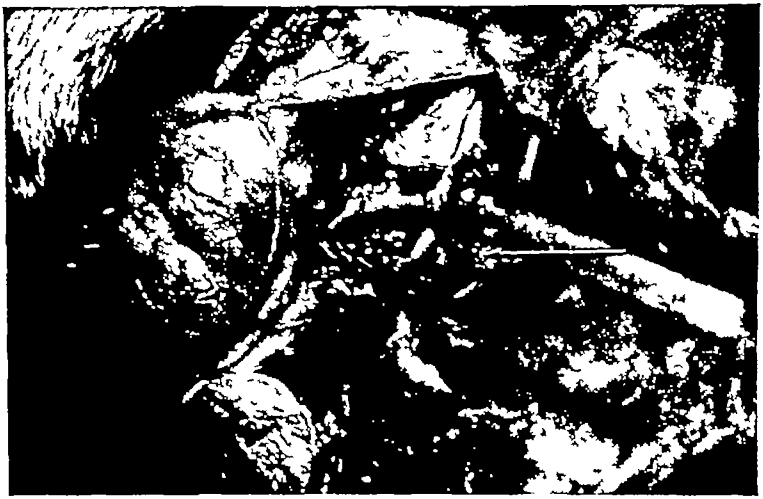

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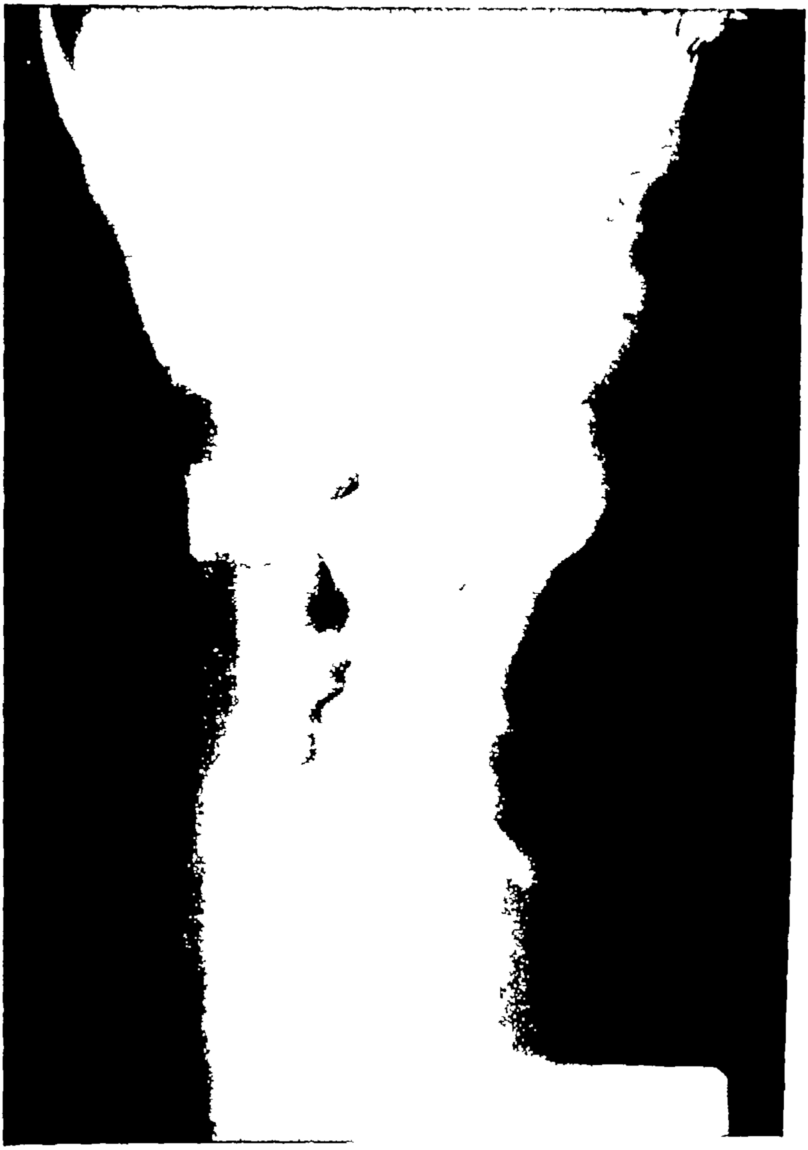


Fig 12 Dog No 1—Two weeks post-vagotomy right Barium swallow shows no essential change from unoperated condition

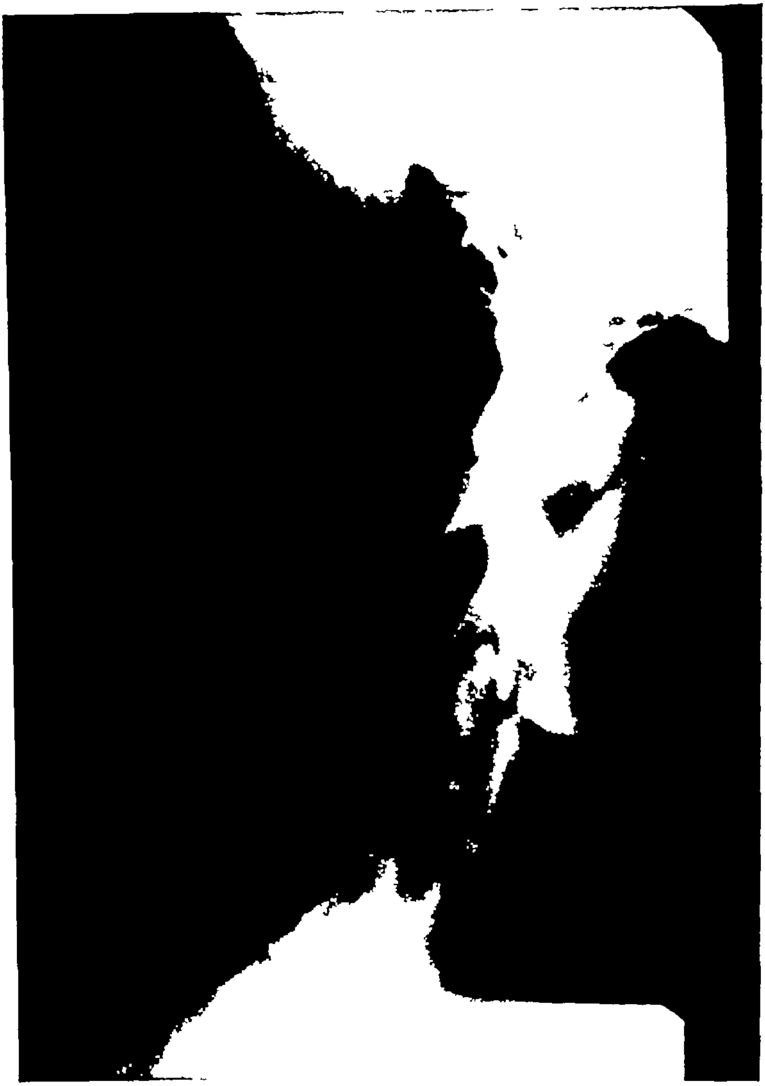
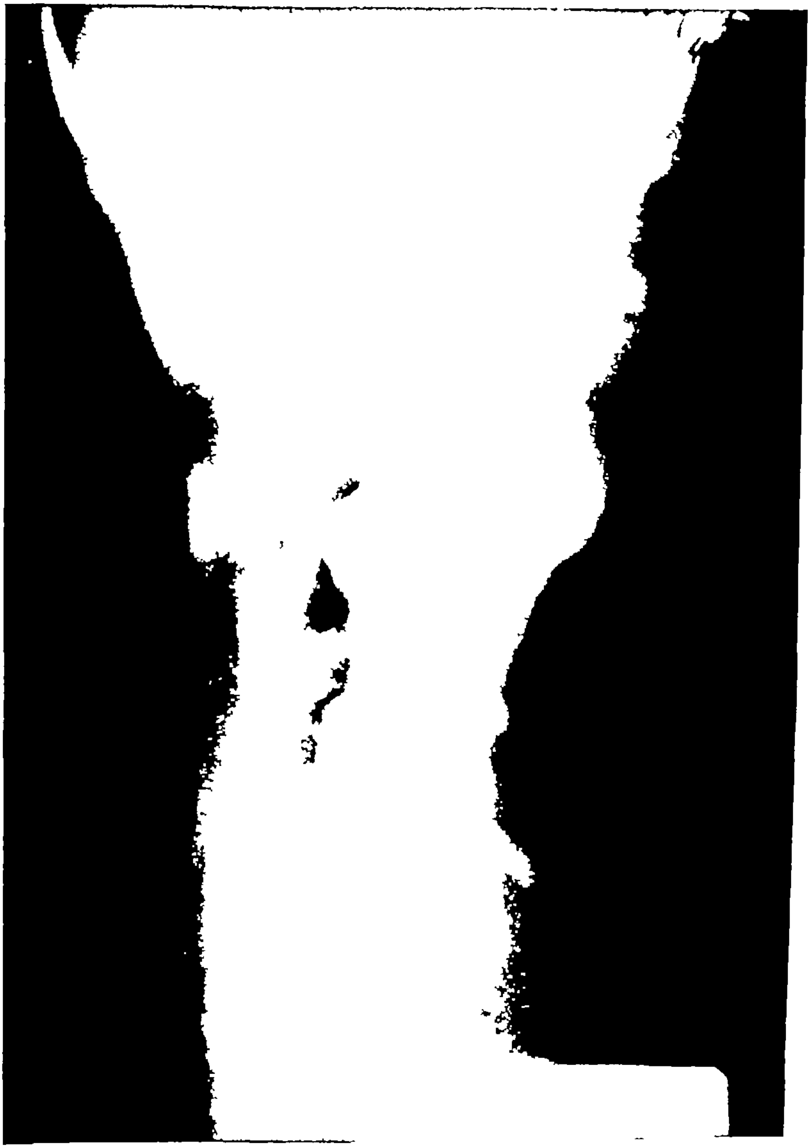


Fig 13 Dog No 1—Two weeks post-vagotomy right. No essential change from unoperated condition



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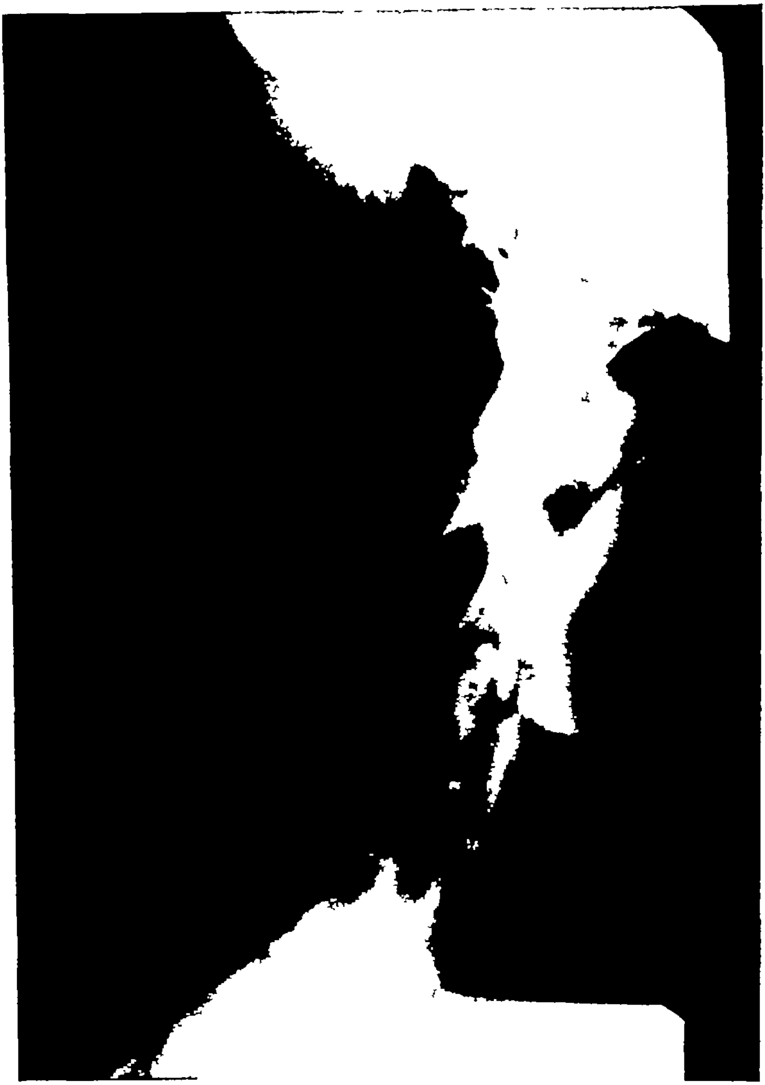

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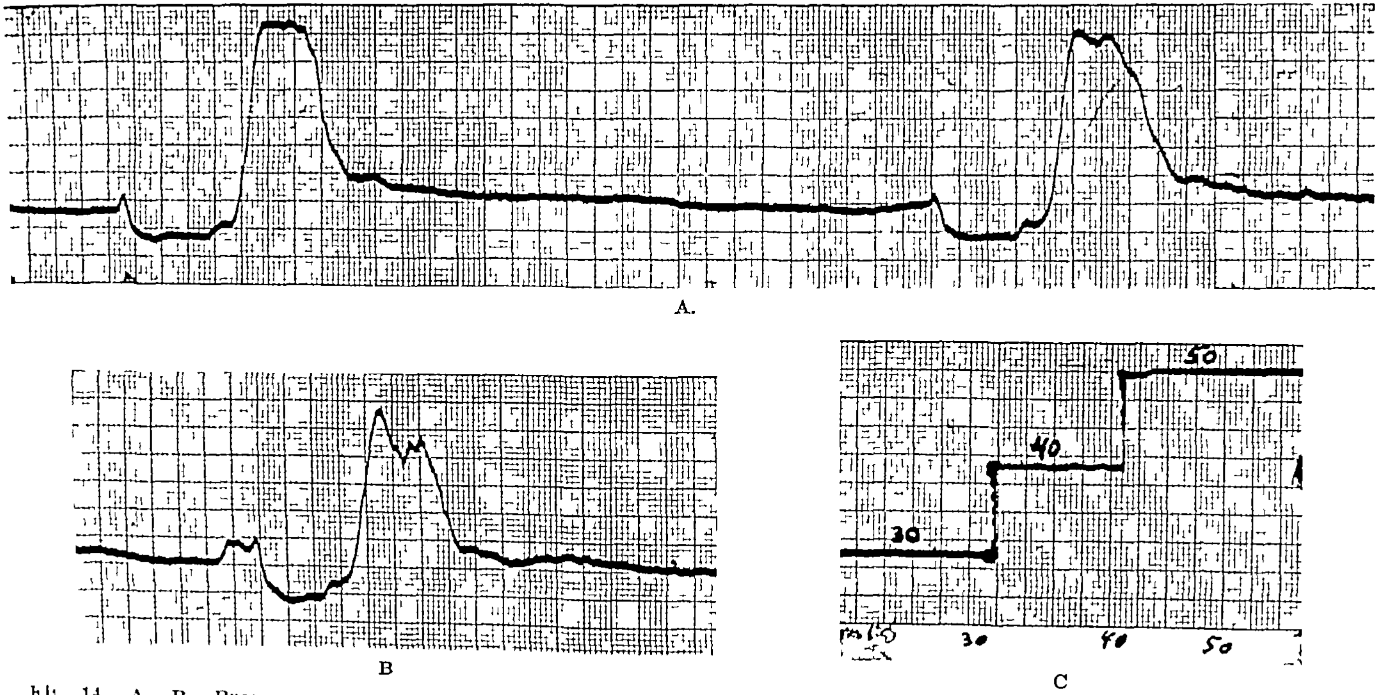


Fig. 14 A B—Pressure recording of deglutition immediately after unilateral vagotomy C—Calibration The relaxation phase is much less prominent than before operation

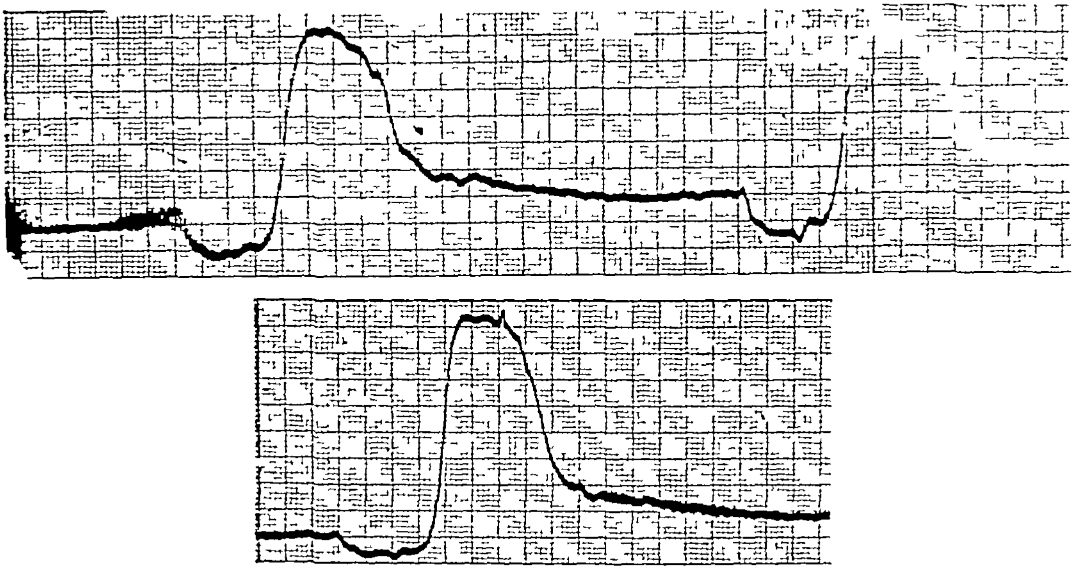


Fig 15 Pressure recordings during deglutition ten days after unilateral vagotomy Show minimal relaxation

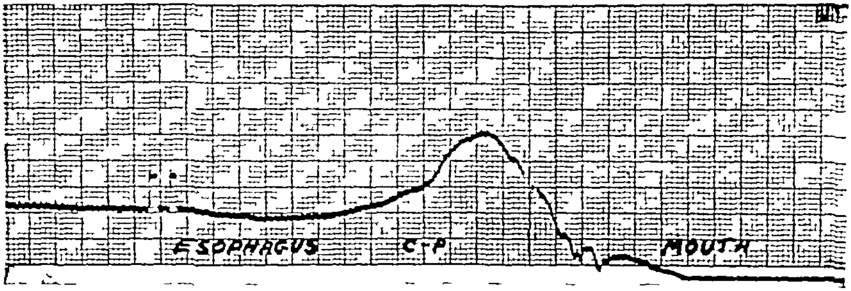
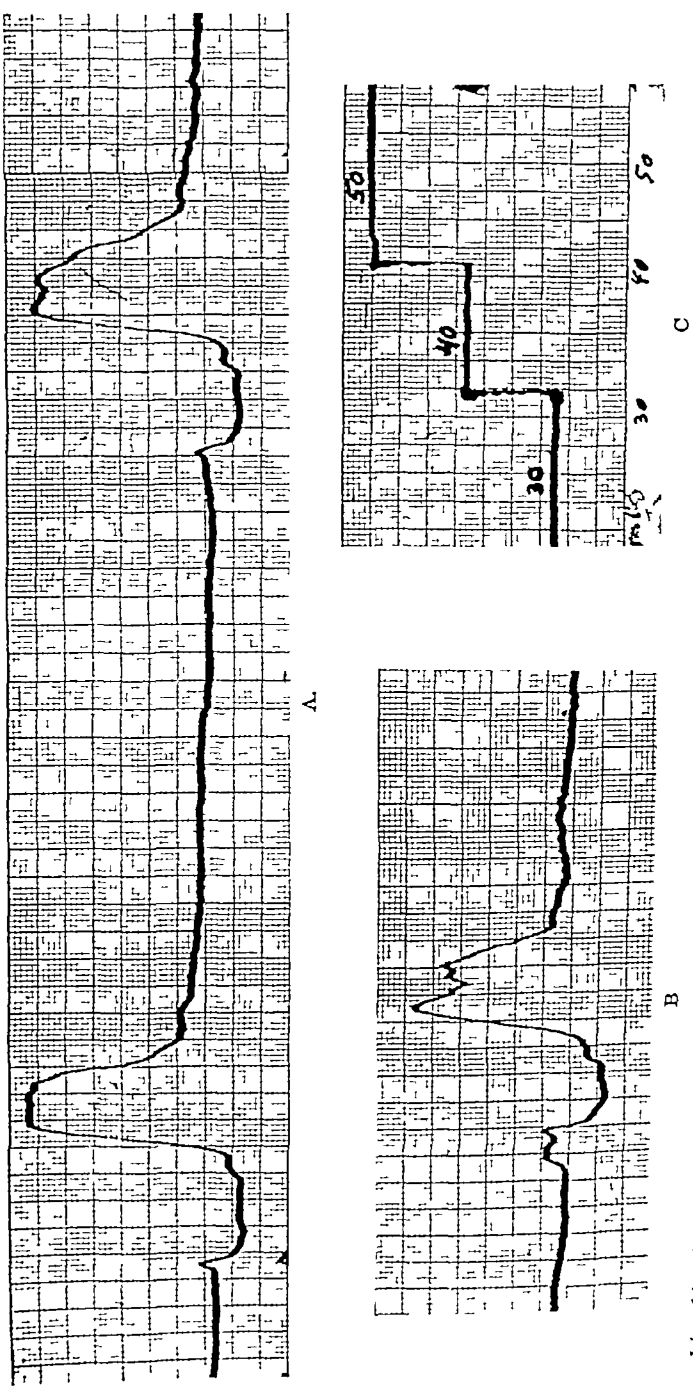


Fig 16 High-pressure area at cricopharyngeus after unilateral vagotomy No essential change from pre-operative condition

since the pressure capsule when pulled up through this area from the esophagus showed the usual pressure rise when passing the cricopharyngeus (see Fig 16)

SECTION OF BOTH VAGI

Using the original dog from the first experiment, the left vagus was divided at its point of exit at the base of the skull three weeks after section of the opposite vagus



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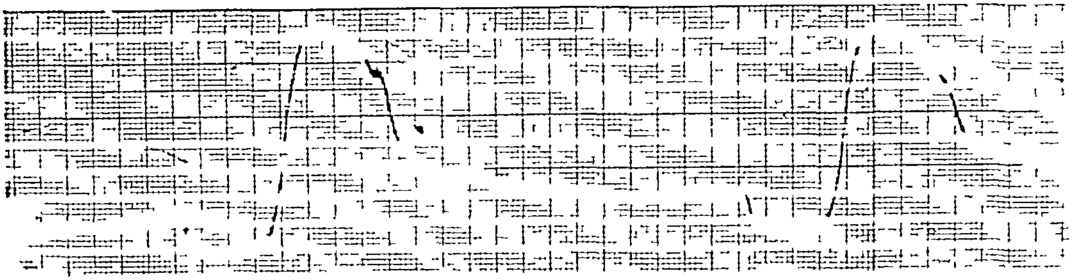

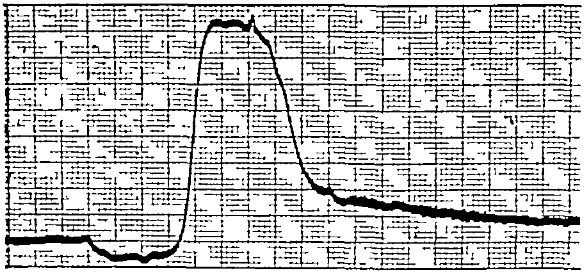

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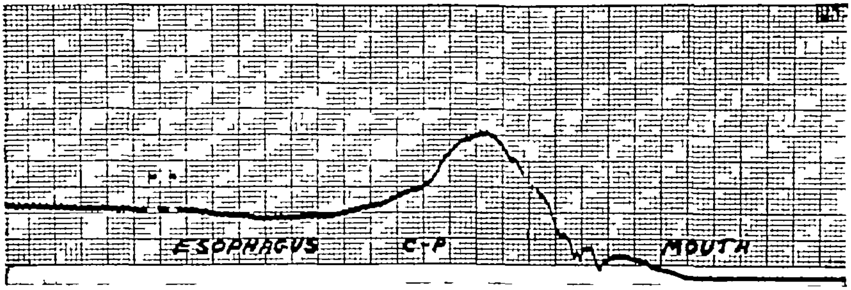

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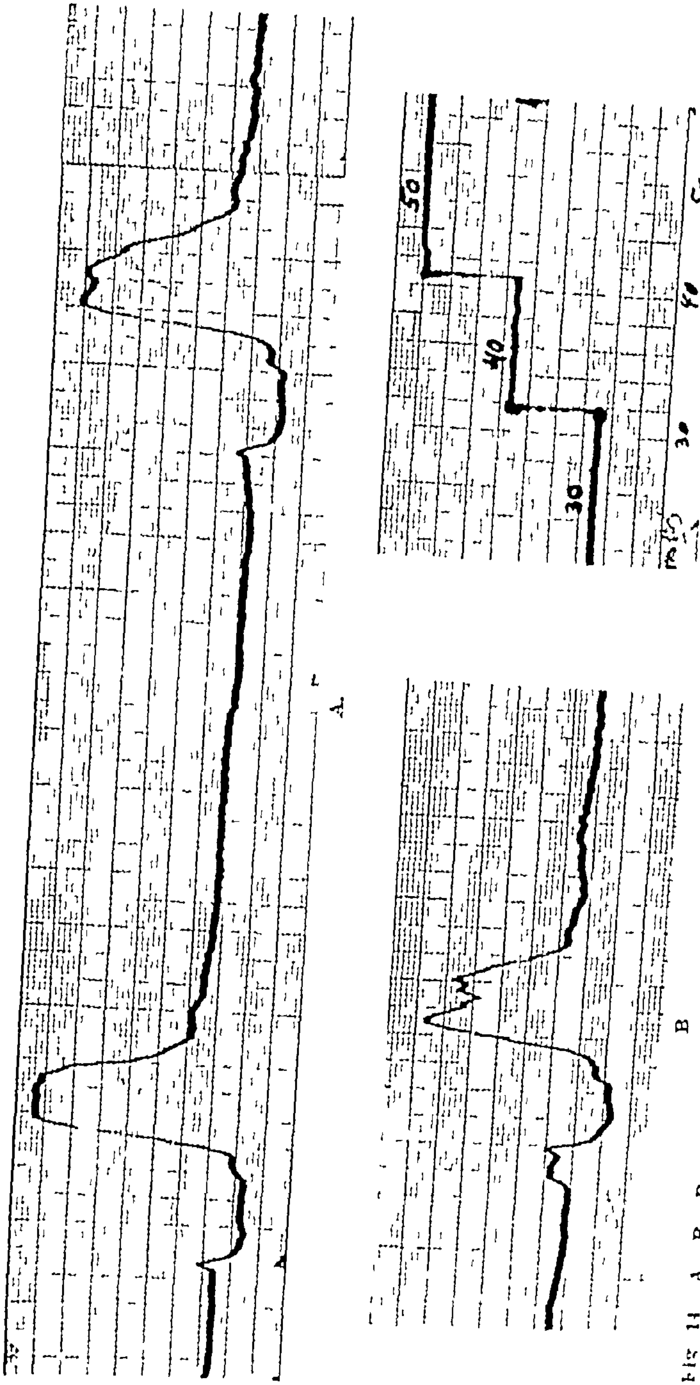

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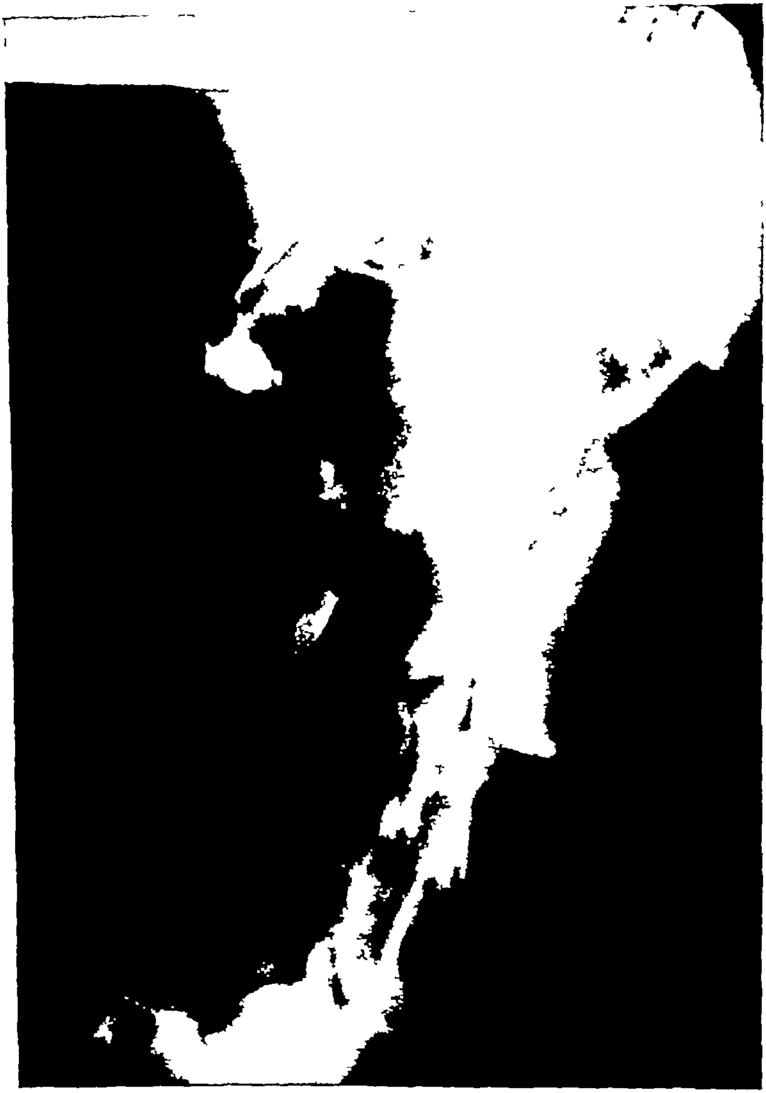


Fig 18 Dog No 1 24 hours after division of second vagus Barium lies in valleculae pharynx upper esophagus and trachea.

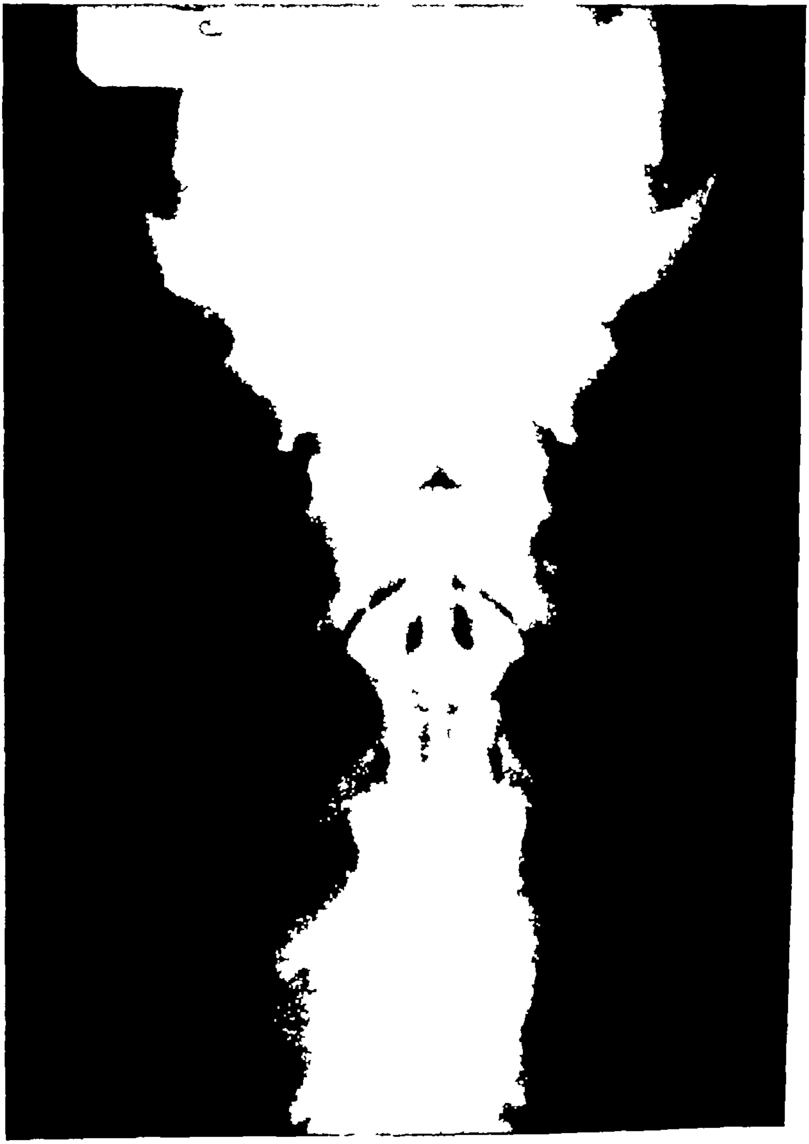


Fig 17 Dog No 1 24 hours after division of second vagus Barium lies in valleculae and in trachea

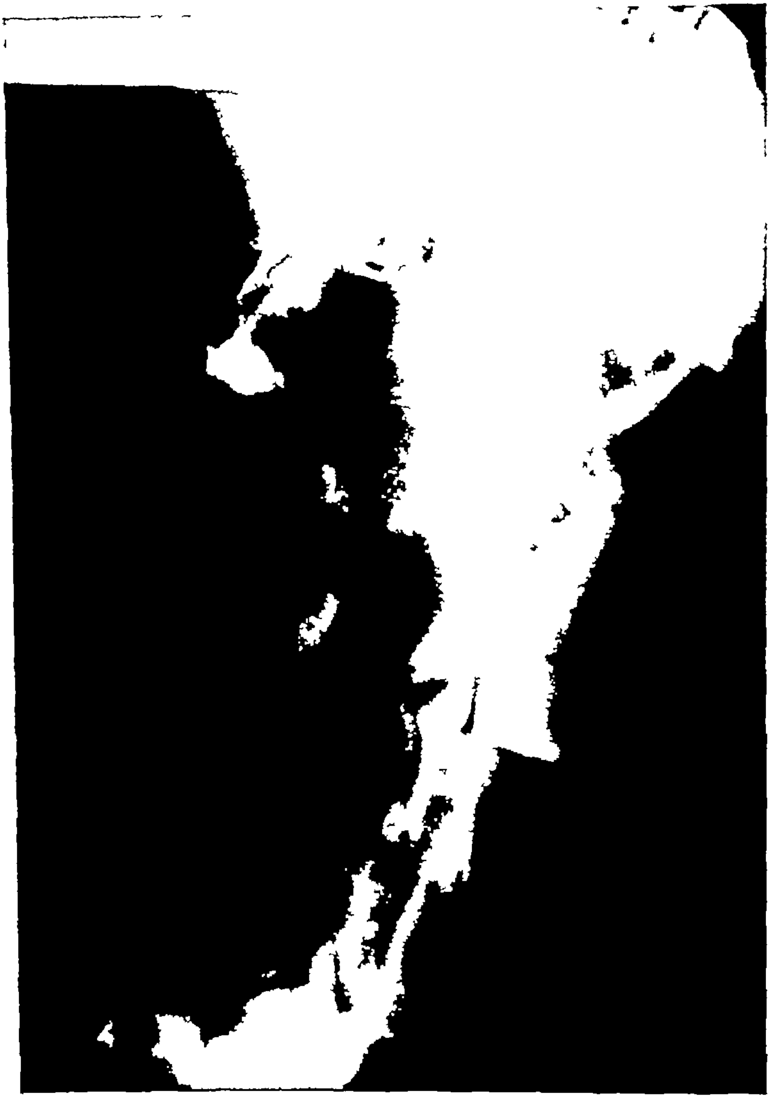


Fig 18 Dog No 1 24 hours after division of second vagus Barium lies in valleculae pharynx, upper esophagus and trachea.

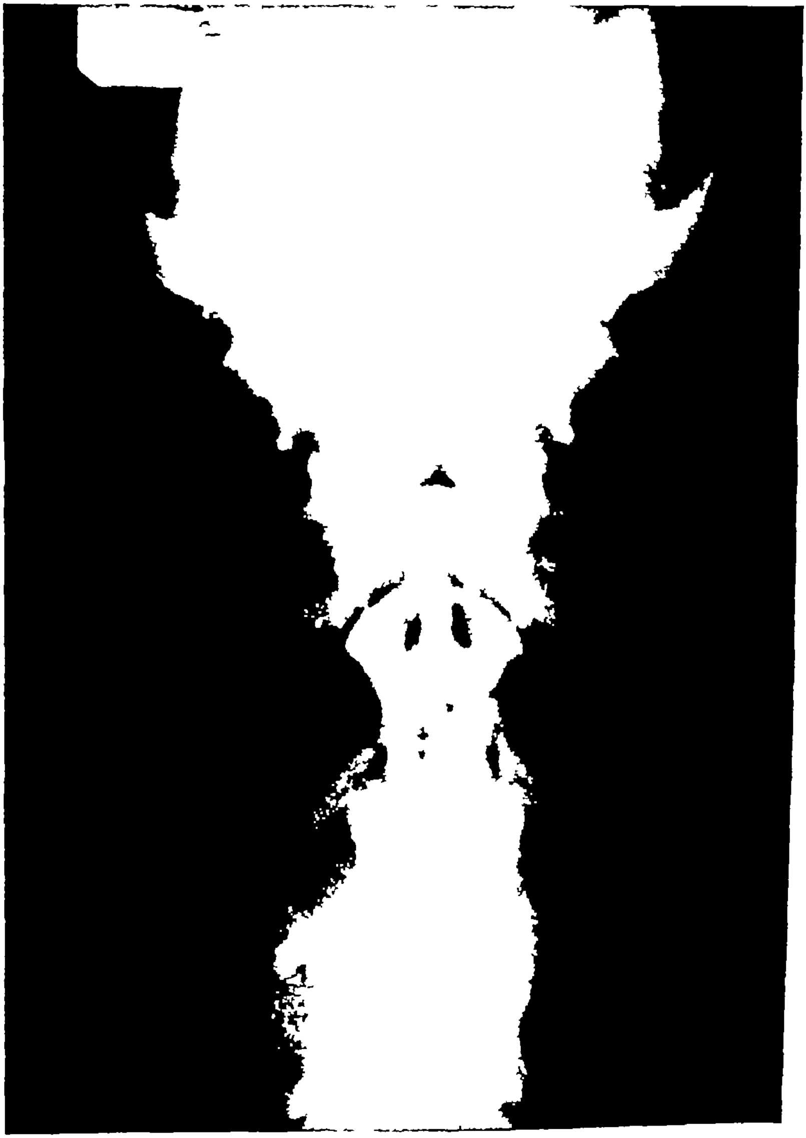
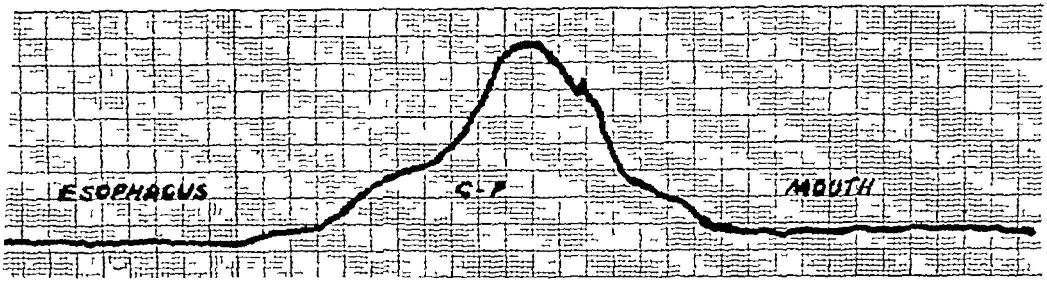
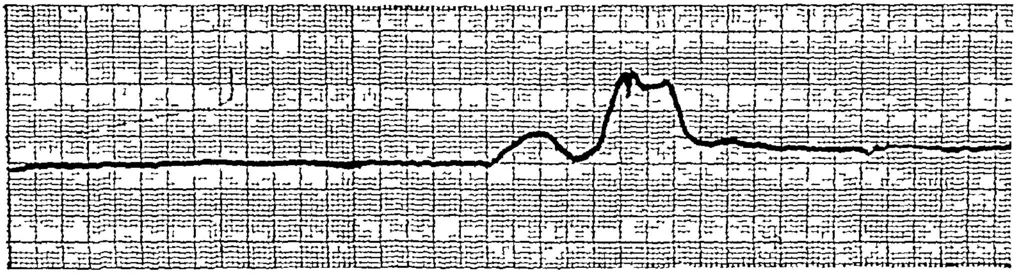


Fig 17 Dog No 1 24 hours after division of second vagus Barium lies in valleculae and in trachea



ig 21 Tracing of original recording of high-pressure area at cricopharyngeus following ıteral vagotomy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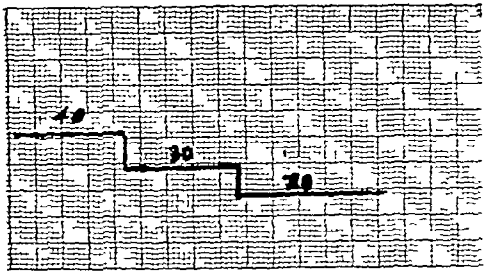

B

Fig 22 A.—Tracing of original recording of deglutition pattern following bilateral vagotomy Relaxation phase is absent. B—Calibration

the moment the second vagus was sectioned (see Fig 20) There was a slight, but definite increase in pressure at the time the vagus was sectioned The cable was then reinserted into the thoracic esophagus, slowly pulled upward through the cricopharyngeus area, where the high-pressure area was encountered as in the previous experiments (see Fig 21)

Swallow patterns showed complete absence of relaxation of the cricopharyngeus during the act of deglutition (see Fig 22)

Deglutition Following recovery from anesthesia, the dog exhibited obvious dysphagia, throwing his head upward and backward in an attempt to swallow liquid

Endoscopic Examination Both vocal cords were paralyzed in a paramedian position Saliva was collected in the lower recesses of the pharynx

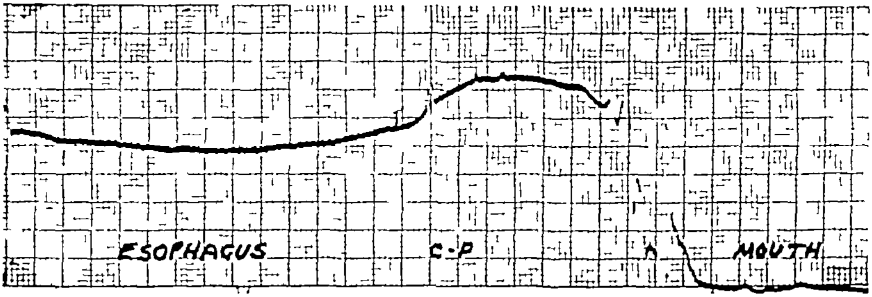

Fig 19 High-pressure area at cricopharyngeus following bilateral vagotomy

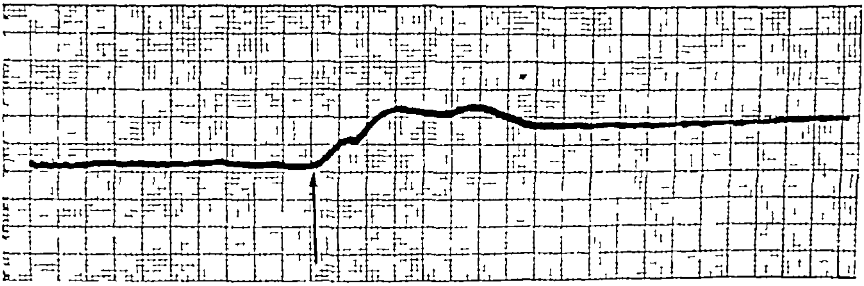

Fig 20 Pressure rise at cricopharyngeus at moment of section of second vagus This and the following two figures are tracings of technically unsatisfactory originals

X-ray Barium mixture was found puddled throughout the pharynx, with some aspiration into the trachea Lateral views showed no significant changes in the soft tissue patterns on the posterior or anterior walls (see Figs 17, 18)

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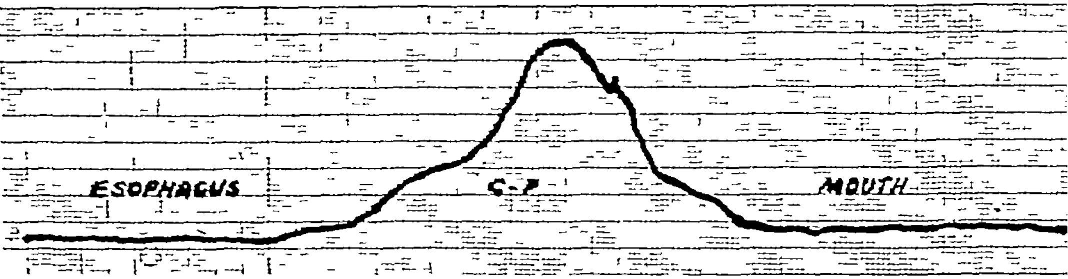
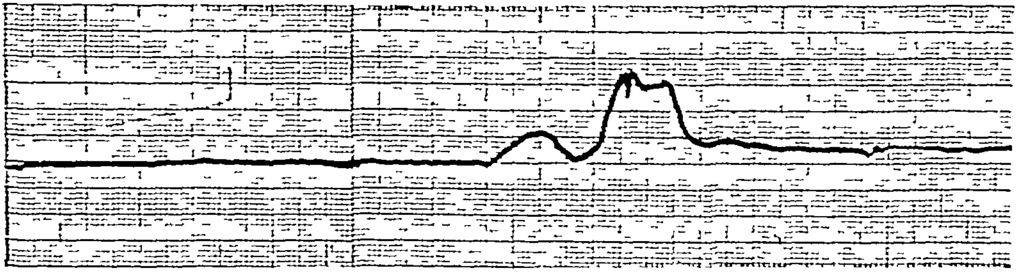


Fig 21 Tracing of original recording of high-pressure area at cricopharyngeus followin bilateral vagotomy



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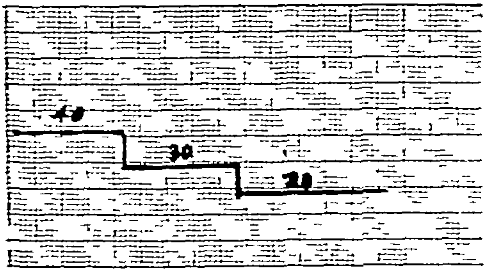

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Fig 22. A—Tracing of original recording of deglutition pattern following bilateral vagotomy Relaxation phase is absent. B—Calibration

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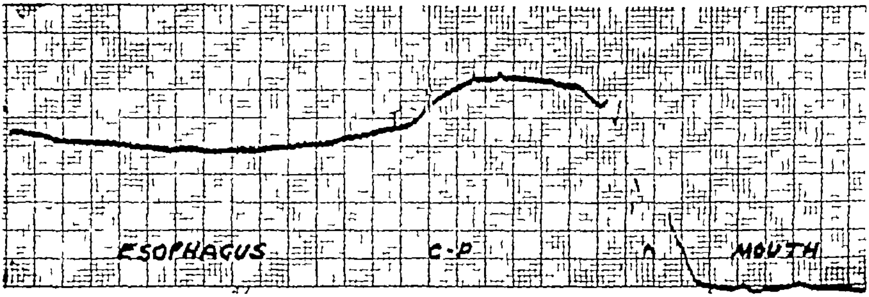
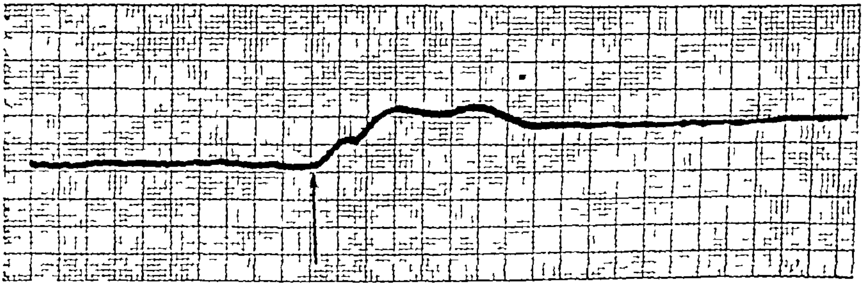


Fig 19 High-pressure area at cricopharyngeus following bilateral vagotomy



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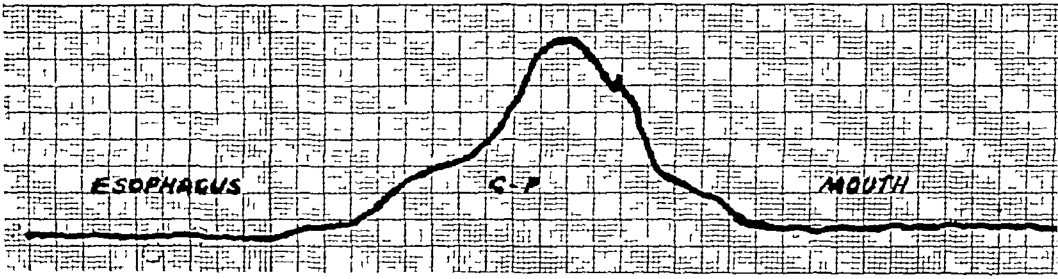
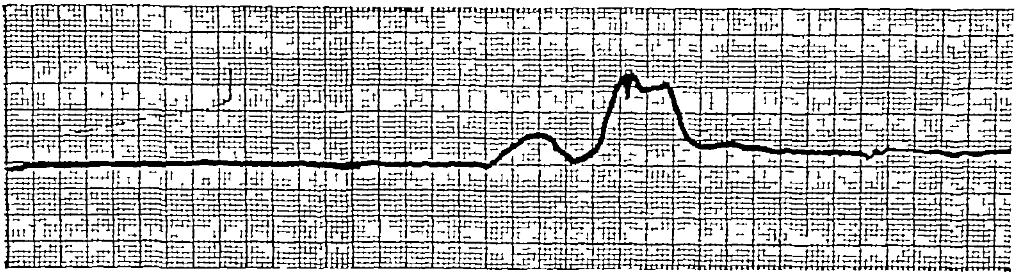


Fig 21 Tracing of original recording of high-pressure area at cricopharyngeus followi bilateral vagotomy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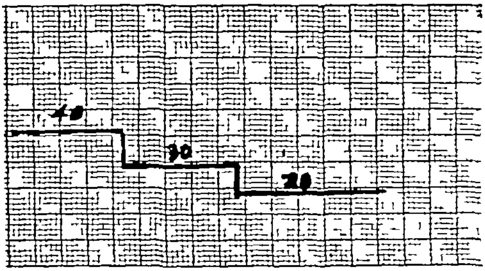

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Fig 22 A —Tracing of original recording of deglutition pattern following bilateral vagotomy Relaxation phase is absent. B —Calibration

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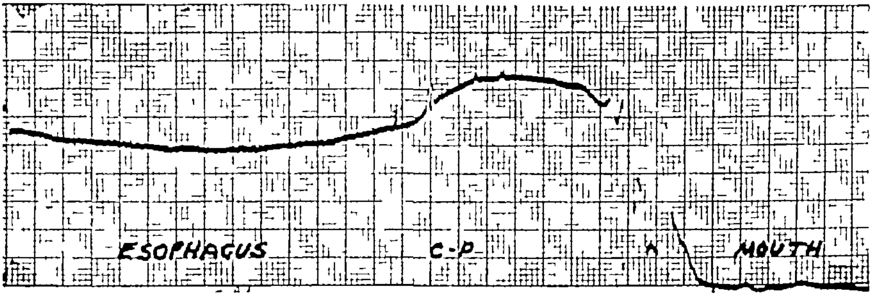

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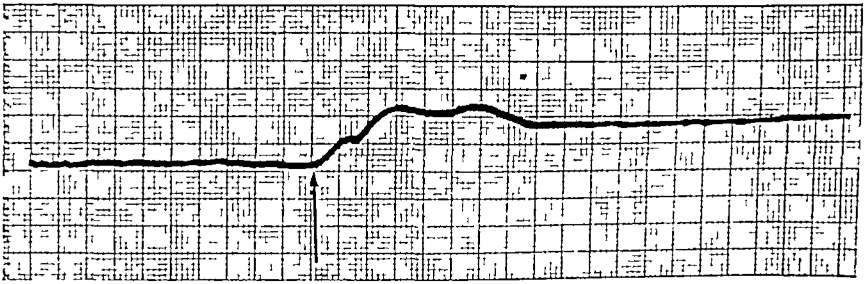

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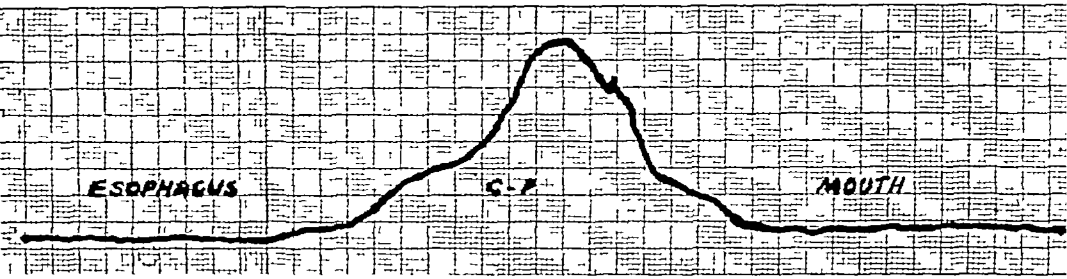


Fig 21 Tracing of original recording of high-pressure area at cricopharyngeus followin ilateral vagotomy

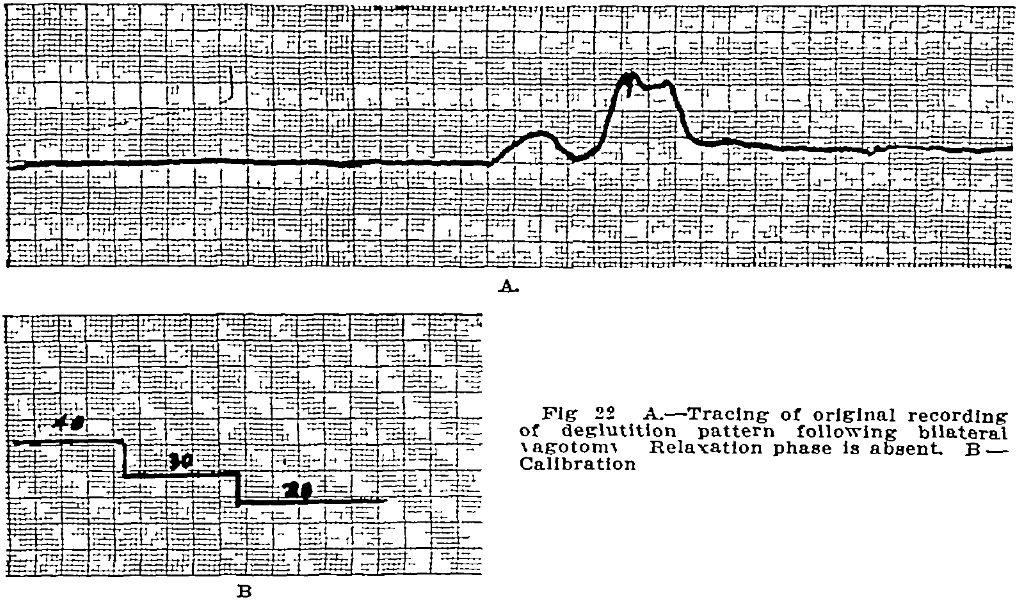


Fig 22 A.—Tracing of original recording of deglutition pattern following bilateral vagotomy Relaxation phase is absent. B—Calibration

the moment the second vagus was sectioned (see Fig 20) There was a slight, but definite increase in pressure at the time the vagus was sectioned The cable was then reinserted into the thoracic esophagus, slowly pulled upward through the cricopharyngeus area, where the high-pressure area was encountered as in the previous experiments (see Fig 21)

Swallow patterns showed complete absence of relaxation of the cricopharyngeus during the act of deglutition (see Fig 22)

DISCUSSION

Section of both vagi produces a condition in which the cricopharyngeus does not relax during the act of swallowing This is probably due to a relative overactivity of the sympathetic supply, and probably explains the dysphagia resulting from nuclear or high cervical lesions of the vagus nerves Paralysis of the remaining constrictor muscles resulting from such lesions undoubtedly contributes to the dysphagia, but does not, in itself, make swallowing impossible, as shown by Meltzer, in cutting the middle and inferior constrictor muscles - The real blockade is produced by the tight cricopharyngeus, whose failure of relaxation, as shown in Fig 22, suggests achalasia as it is encountered at the lower esophageal ostium

STIMULATION OF THE VAGUS AND SYMPATHETIC

In order to eliminate any possible pressures resulting from the rocking of the thyroid on the cricoid cartilages by the cricothyroid muscle during this experiment, the cricothyroideus was first divided bilaterally in a normal dog The vagus nerve was exposed near the base of the skull after dividing the digastric muscle so that the stimulating electrode could be placed between the ganglion nodosum and the jugular foramen The dog was lightly anesthetized with 5 per cent nembutal

X-ray Barium mixture was inserted into the dog's pharynx and the dog made to swallow by stroking the posterior wall of the pharynx The right vagus nerve was then stimulated, but inspection of the neck after the films were taken showed that the electrode had been pulled downward along the vagus so that the entire vagosympathetic trunk had been stimulated AP views show a marked deviation of the trachea to the left, away from the side of vagal stimulation, as one would expect, with relaxation of the supporting musculature on one side While no conclusions are drawn from this finding because a slight tracheal deviation was found pre-operatively, the finding, nevertheless, warrants further investigation (see Figs 23, 24)

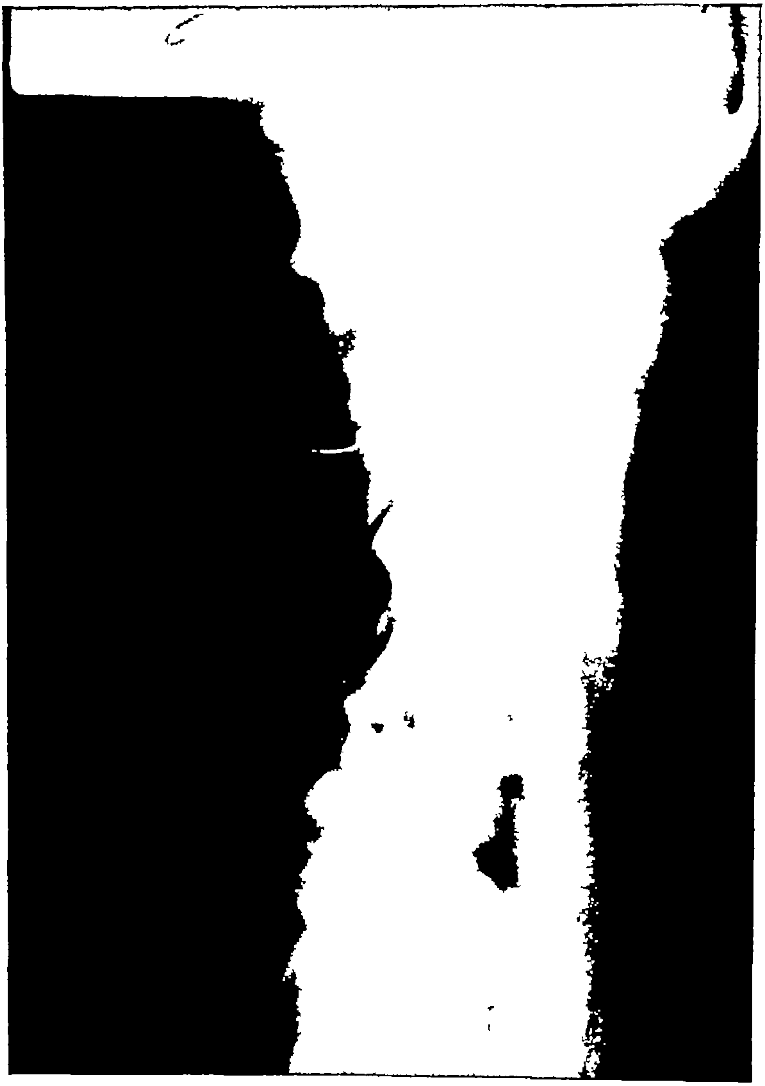


Fig 23 Stimulation of right vagus dog No 2 Tracheal deviation to opposite side is suggestive of relaxation of right constrictor muscle support but inconclusive

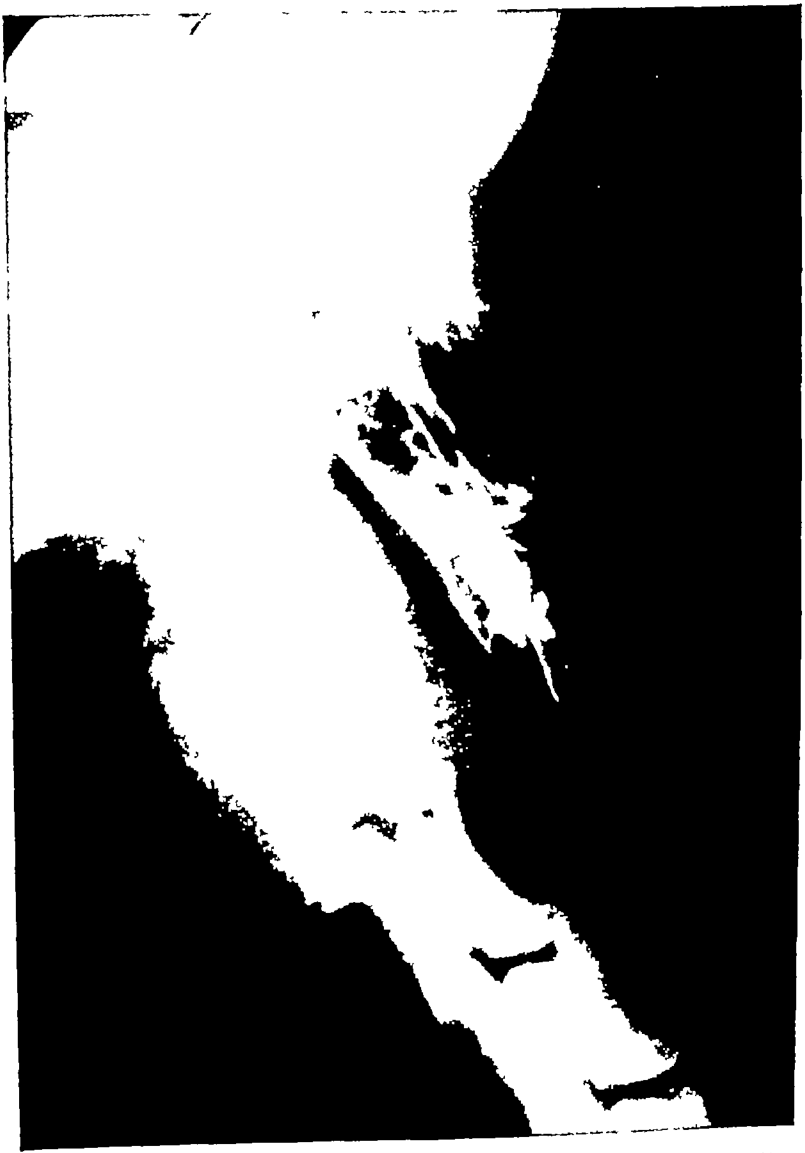
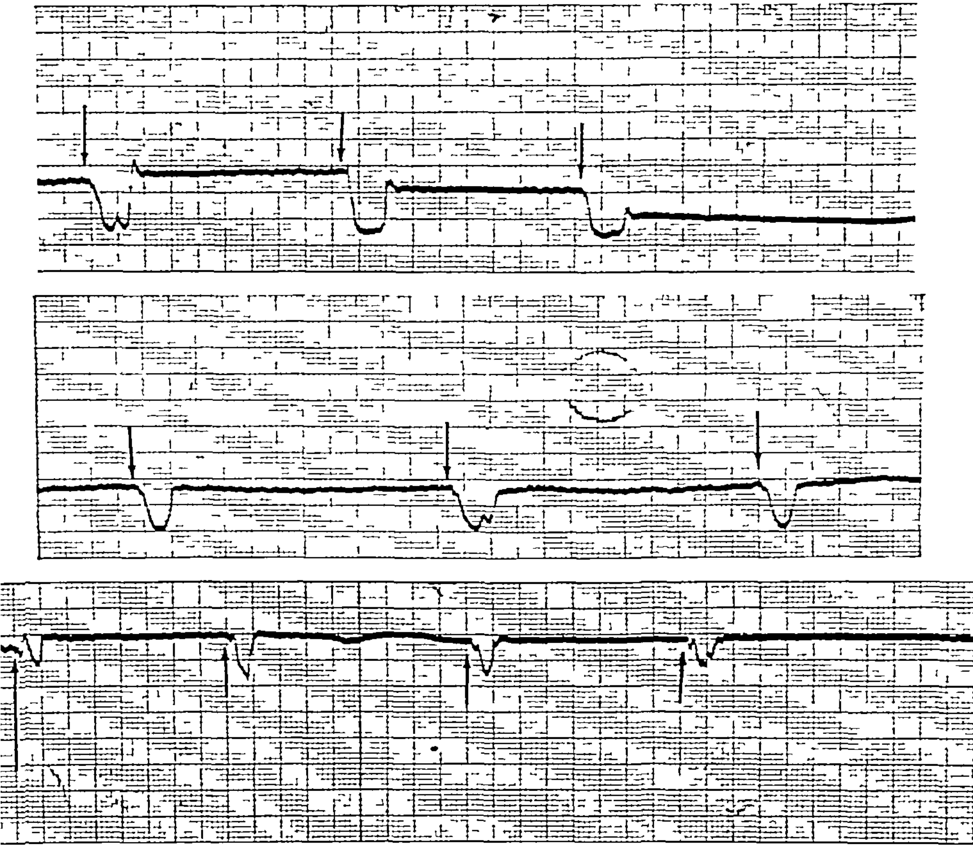


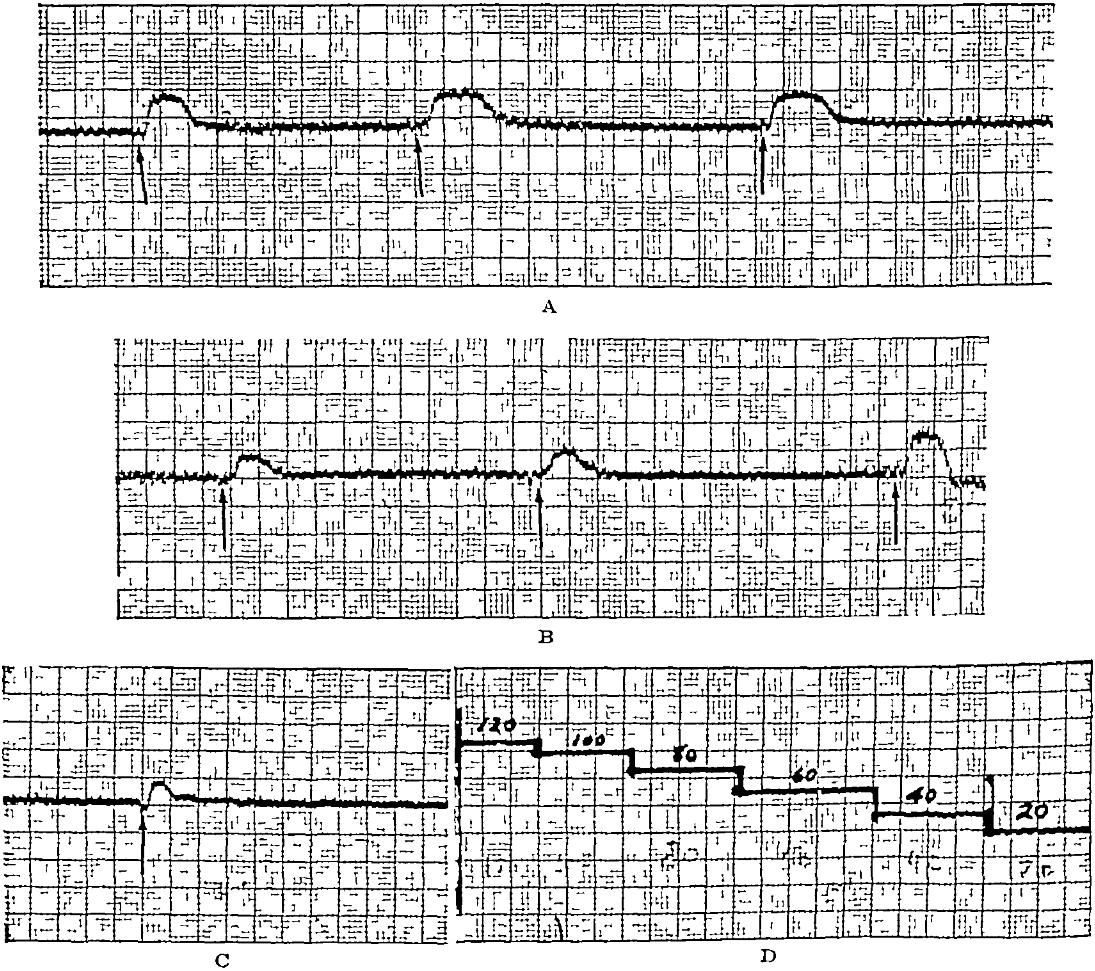
Fig 24 Stimulation of right vagus dog No 2 No significant findings



: 25 **Faradic stimulations (arrows) of right vagus Sharp relaxation of cricopharyng**
own.

Pressure Studies The faradic stimulus was adjusted to a low intensity so that vagus stimulation did not produce a swallow or cause noticeable movements of the regional muscles For sympathetic stimulation, it was assumed that the supply to the cricopharyngeus comes from the superior cervical sympathetic ganglion[17] Stimulation of the vagus above the ganglion nodosum produced a sudden sharp drop in the resting pressure of the cricopharyngeus muscle (see Fig 25)

Stimulation at the superior cervical sympathetic ganglion produced a sharp rise in pressure in the cricopharyngeus zone (see Fig 26) Controls were run with finger pressure over



A

B

C

D

Fig 26 A B C —Faradic stimulation (arrows) of superior cervical sympathetic ganglion Definite pressure increases are shown D —Calibration

the cricoid cartilage, producing positive deflections (see Fig 27) The faradic stimulator was held near, but not on the nerve, to determine changes due to electrical conditions (see Fig 28) There were none found The stimulator was also applied to the tongue in order to check the effect of movements of adjacent organs There were no significant effects noted (see Fig 29)

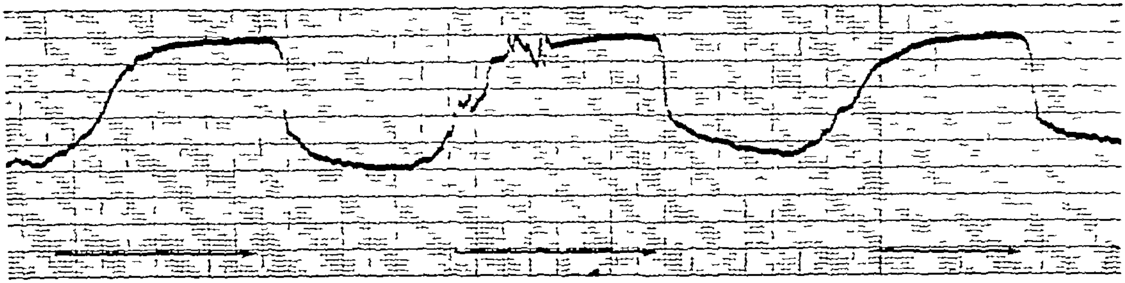


Fig 27 Control finger pressure on cricoid cartilage showing upward deflection with increase in pressure (arrows)

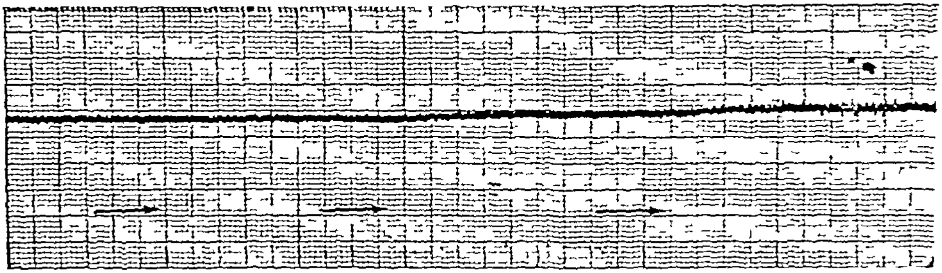


Fig 28 Control Electrode near but not on the nerve

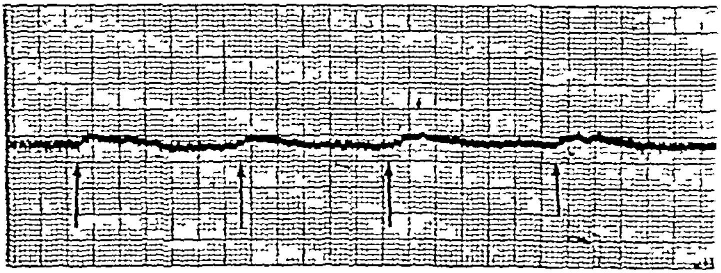


Fig 29 Control Electrode stimulating tongue No significant pressure changes at cricopharyngeus

DISCUSSION

The consistent drop in pressure with vagal stimulation, and the consistent rise in pressure with sympathetic stimulation indicates that only one type of activity is mediated by each of the two autonomic divisions It adds further support to Sjoberg's impression that the sphincteric closure at the crico-

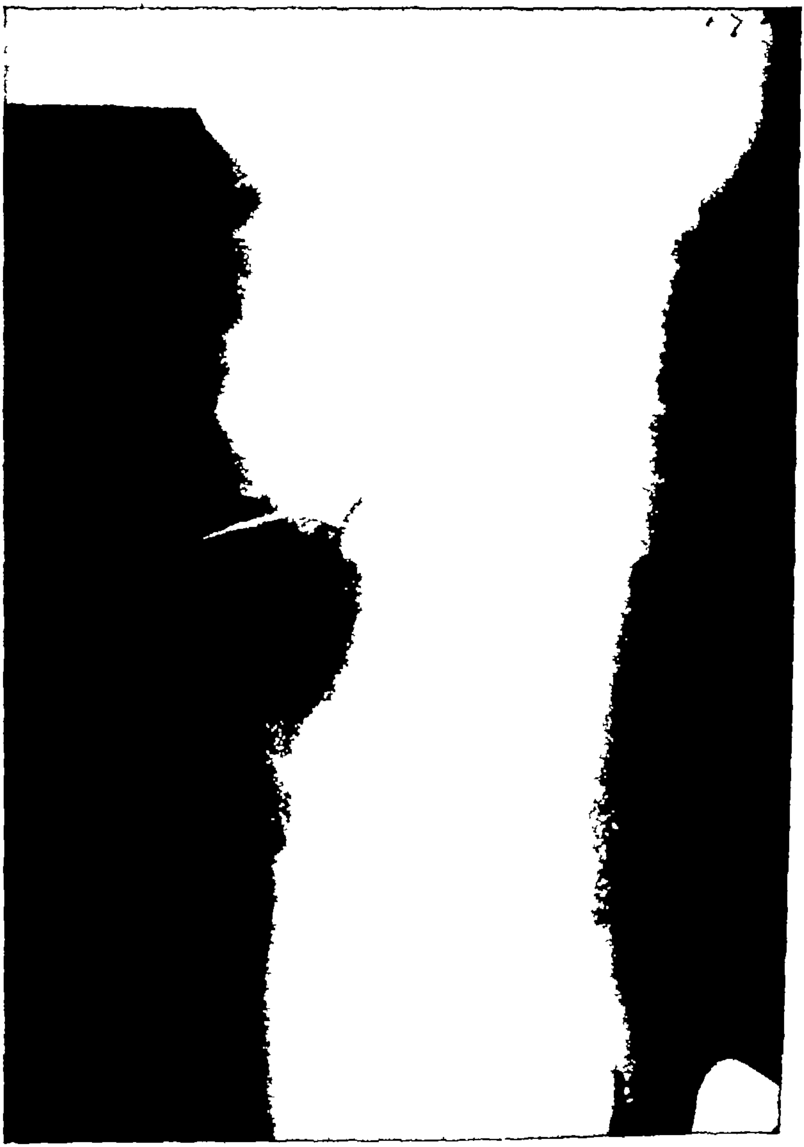


Fig 30 Faradic stimulation of cricopharyngeus muscle Less tracheal deviation but no significant changes

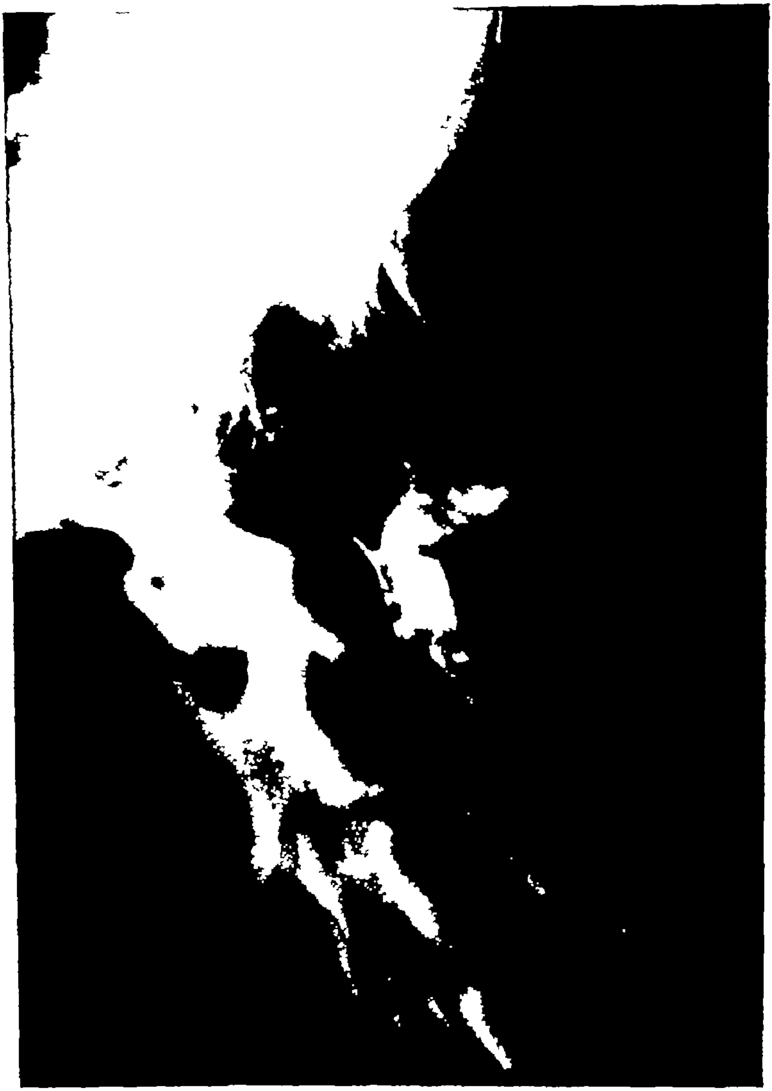


Fig 31 Faradic stimulation of cricopharyngeus No significant changes

pharyngeus following bilateral vagotomy is due to unopposed sympathetic activity, and that this condition may occur clinically

STIMULATION OF THE CRICOPHARYNGEUS

Stimulation of the cricopharyngeus muscle itself produced no appreciable change on X-ray examination from the normal resting stage There appeared to be a slight tilt of the thyroid cartilage on the cricoid, but it is not definite enough to be conclusive (see Figs 30, 31)

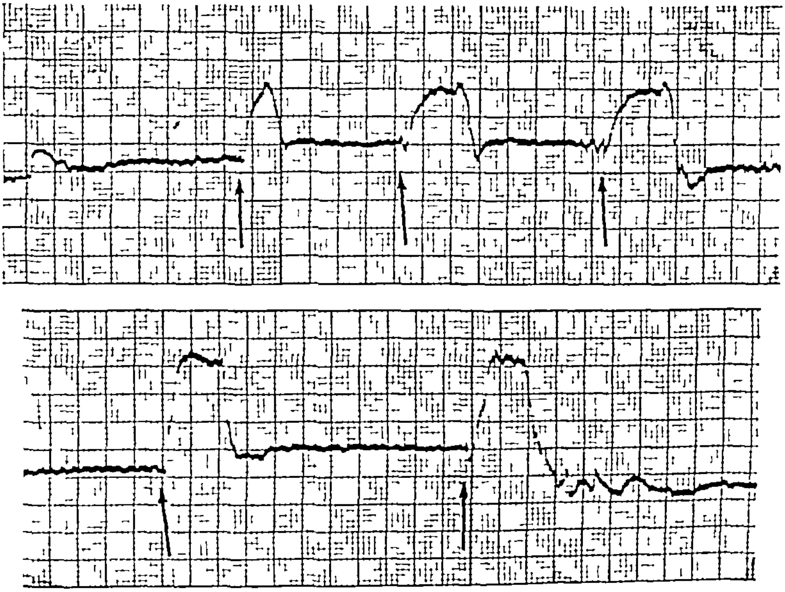


Fig 32 Faradic stimulation of cricopharyngeus muscle Sharp increase in pressure

Pressure Studies Pressure readings during stimulation of the cricopharyngeus muscle show definite contractions with each stimulus (see Fig 32)

SECTION OF THE CRICOPHARYNGEUS

In order to determine whether the thyropharyngeus portion of the inferior constrictor has any tonic action in holding the larynx back against the vertebrae the cricopharyngeus action was eliminated by dissecting the cricopharyngeus off both sides of the cricoid at its points of attachment

Deglutition The dog exhibited no dysphagia over an observation period of one month The right vocal cord was found to be abducted immediately postoperatively, but its action had returned to normal when it was examined about three weeks later

Endoscopic Examination There was no collection of food or saliva anywhere in the pharynx, and the annular area noted in the normal dog was found again to be present behind the cricoid cartilage

X-ray Swallowing performed normally No changes in the soft tissue pattern of the pharynx or hypopharynx There is no change in the position of the larynx as compared to its distance from the posterior wall (see Figs 33, 34)

Pressure Studies Faradic stimulation of the vagus supply to the inferior constrictor muscle produced only a barely noticeable drop from resting pressure (see Fig 35)

DISCUSSION

Complete separation of the cricopharyngeus from the cricoid cartilage is compatible with normal deglutition Endoscopic examination shows the annular constriction found prior to surgery Photomicrographs prepared from this area show that the ridge is composed chiefly of mucous glands (see Figs 36, 37, 38) Stimulation of the vagus after sectioning the cricopharyngeus produced practically no change in the resting pressure in this area, showing that the upper or thyropharyngeus portion of the inferior constrictor has little or no tonic action in supporting the larynx Comparison of pressure readings before and after sectioning the cricopharyngeus shows that this muscle is normally in a state of tonic contraction

SUMMARY

1 The motor activity of the dog's cricopharyngeus muscle was studied during its resting state and during deglutition

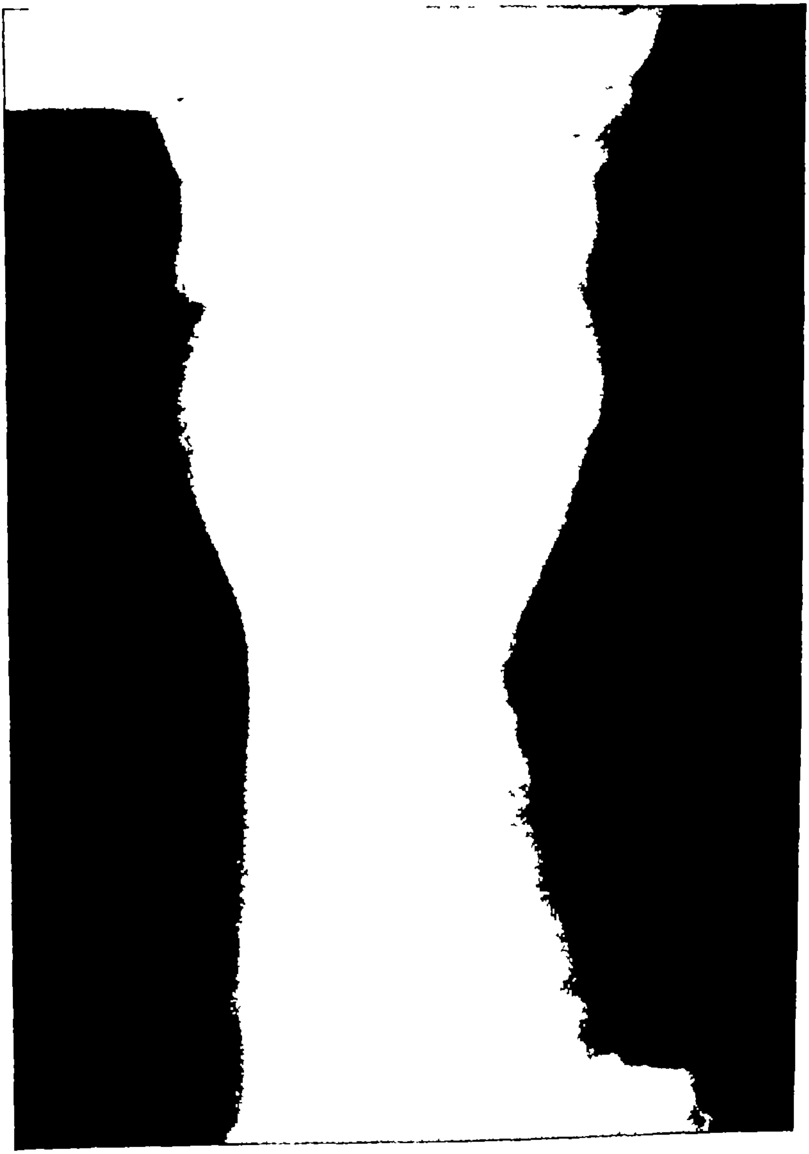


Fig 3 Following section of cricopharyngeus and thyropharyngeus bilaterally No significant changes

Fig 34 Following section of cricopharyngeus and thyropharyngeus No significant changes.

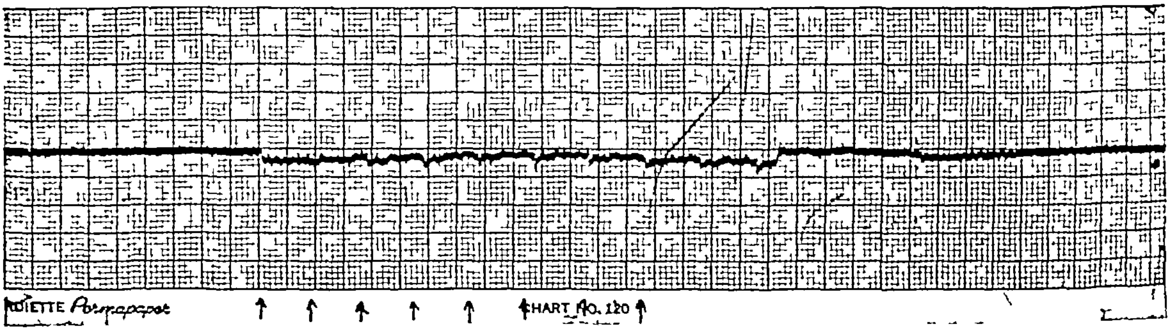


Fig 35 Faradic stimulation of vagus following section of cricopharyngeus muscle The usual drop in pressure is not seen

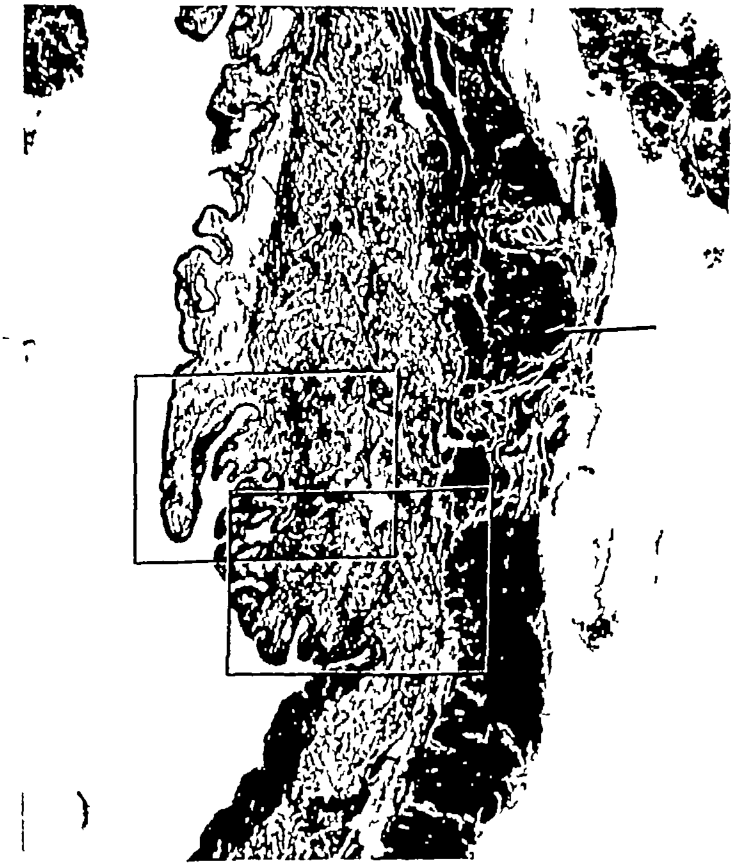


Fig 36 Saggital section of wall of hypopharynx at level of cricopharyngeus (arrow) and annular fold (×12) See Fig 5

2 By sectioning or stimulating each of the two major components of the nerve supply to the cricopharyngeus muscle various states of autonomic imbalance were produced and their effects observed by four methods

A Observations of the dog's ability to swallow food and liquids

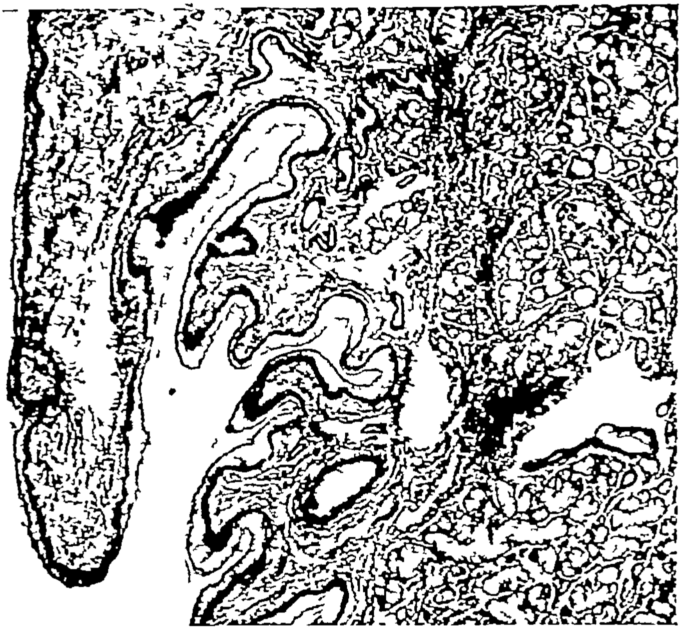


Fig 37 Saggital section through hypopharyngeal fold (upper square in Fig 36) (×38)

B Endoscopic appearance of the pharynx, larynx and hypopharynx

C Radiologic studies of the hypopharynx

D Intraluminal pressure recordings from the cricopharyngeus sphincter area using a newly developed electronic cable

3 Controls were established for the pressure recordings by the following means

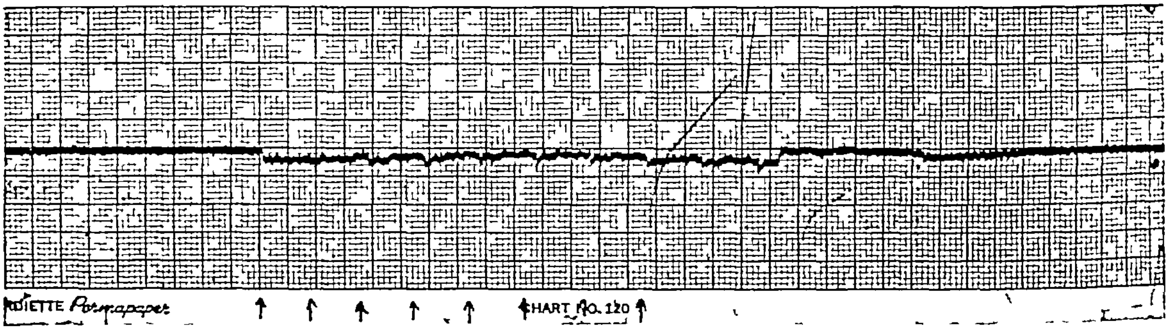
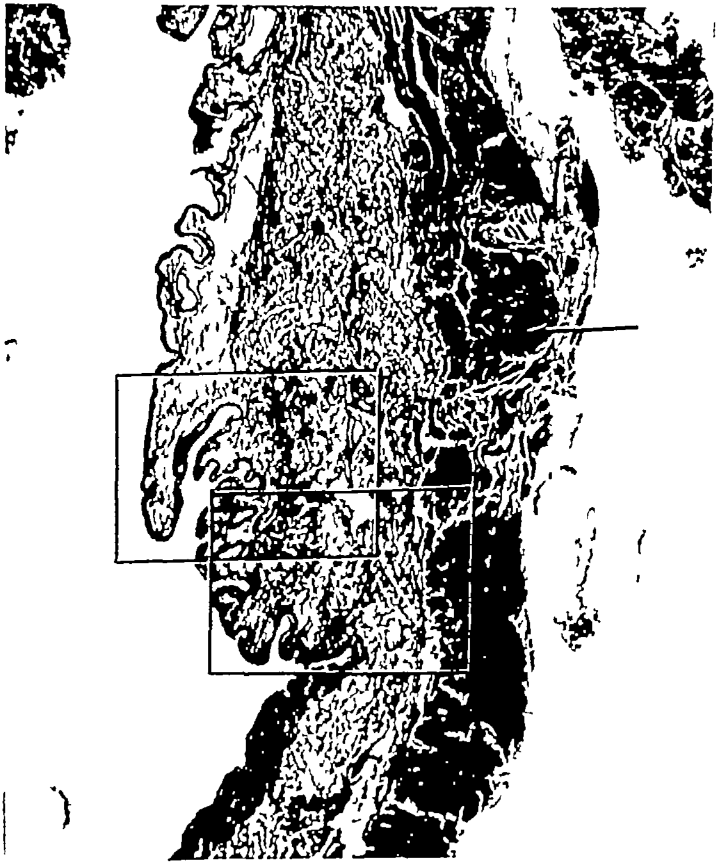


Fig 35 Faradic stimulation of vagus following section of cricopharyngeus muscle The usual drop in pressure is not seen.



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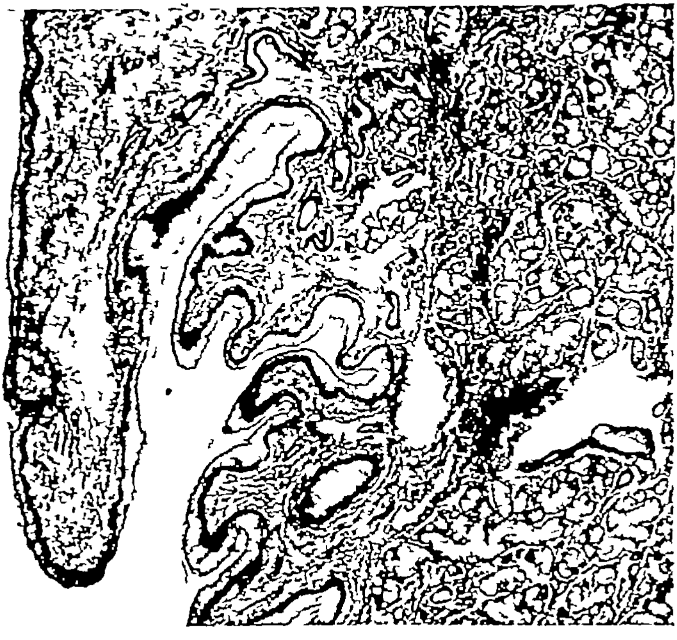

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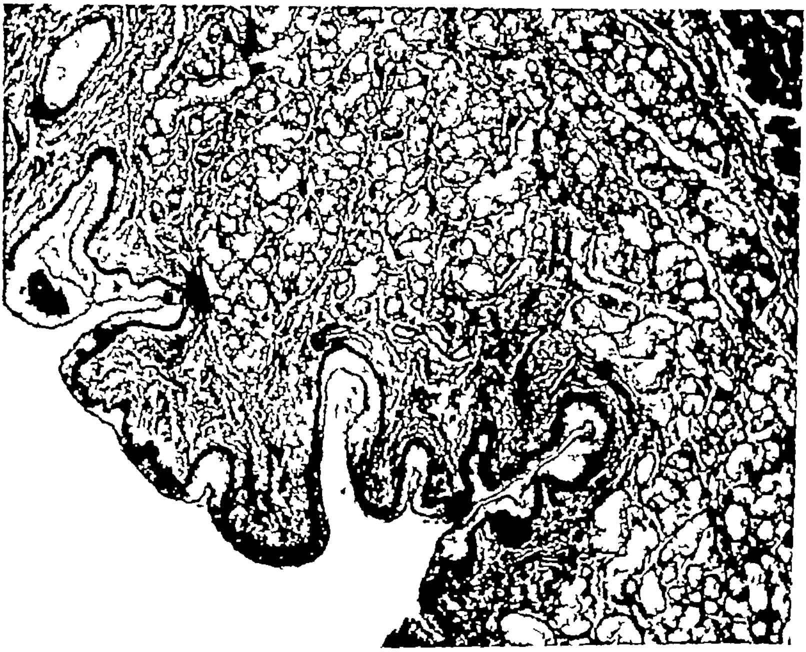

Fig 38 Saggital section through hypopharyngeal fold (lower square in Fig 36) showing large masses of mucous glands (×38)

RESULTS AND CONCLUSIONS

1 The cricopharyngeus muscle was found by pressure recordings to be in a constant state of tonus during its resting stage

2 During normal deglutition the muscle first relaxes then contracts to a pressure level equal to or higher than its resting pressure

3 Unilateral vagus section at base of skull diminishes slightly the relaxation phase of the muscle during swallowing but does not produce dysphagia in the dog

4 Bilateral vagus section at base of skull abolishes the relaxation phase and produces severe dysphagia during the dog's remaining hours of life

5 Faradic stimulation of the vagus branch to the cricopharyngeus produces a sharp relaxation of pressure

6 Stimulation of the superior cervical sympathetic ganglion produces a sharp rise in pressure

7 Relaxation is mediated by the parasympathetic fibers, contraction is mediated by the sympathetic

8 Dysphagia may result from increased tonus in the cricopharyngeus as a result of sympathetic overactivity in lesions affecting the vagus nerves between the nucleus ambiguus and the ganglion nodosum Surgical treatment of this condition would require division of either the muscle itself, or its sympathetic nerve supply

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A DEVICE FOR INTRA-ESOPHAGEAL AND OTHER INTRA-LUMEN PRESSURE RECORDING

ALBERT S FIELD, JR ,*

New Haven, Conn

In a study of the swallowing mechanism described elsewhere,[1] the need for a pressure sensitive capsule arose Pressure changes within the esophagus produced by contraction and relaxation of the cricopharyngeus muscle were to be recorded These pressures are difficult to record, as the cricopharyngeus moves up and down during the act of swallowing, changing the relationship of the muscle to any stationary device in the esophageal lumen[1] A balloon connected by air-filled tubing to an electronic recording system had not produced successful results Brody and Quigley have called attention to the unsatisfactory physical characteristics of balloons Constriction of the balloon produces intraballoon pressures which do not accurately reflect pressures within the space being studied,[2] and in the study of the swallowing mechanism[1] the pressure changes recorded by the intra-esophageal balloon could not be consistently reproduced To overcome this difficulty it was decided to use a pressure sensitive capsule of cylindrical shape and of such dimensions that it would fit within the esophagus at the level of the cricopharyngeus muscle, be in contact with the muscle at all times, yet permit the muscle to slide over it when swallowing occurred It was important that the entire surface of the capsule be capable of responding to alteration in pressure, and that the effect of this response be transmitted to a system which would make a permanent visual record of the pressure variation As a qualitative record of pressure change fulfilled the needs of the experiment, exact quantitative estimate of pressure was not attempted except as required for calibration of the system

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*From the Cardiopulmonary Laboratory Department of Internal Medicine and the Section of Otolaryngology Department of Surgery Yale University School of Medicine

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The pressure sensitive capsule described below (see Fig 1), a modification of the principle described by Lilly and Buchtal and Warburg[4] met the desired requirements A miniature differential transformer of the type described by Gauer and Gienapp[5] was considered, but discarded because it records only end pressures Here the sensitive structure is essentially a variable condenser, the capacitance of which varies when the two metallic surfaces separated by air come closer to each other, or move farther apart, as one is subjected to greater or less pressure than the other Aluminum foil was used for the metallic surfaces, but instead of air a thin sheet of rubber which forms a solid, flexible dielectric was employed to keep them apart The layers of foil and rubber were arranged concentrically to form a cylinder 1 cm in diameter and 5 cm long In order to record directly in a body cavity, rather than remotely as part of a gas or fluid filled system, a flexible water-tight cover protected the condenser from conducting solutions such as fluids in the esophagus, which could make a short circuit between the metallic surfaces

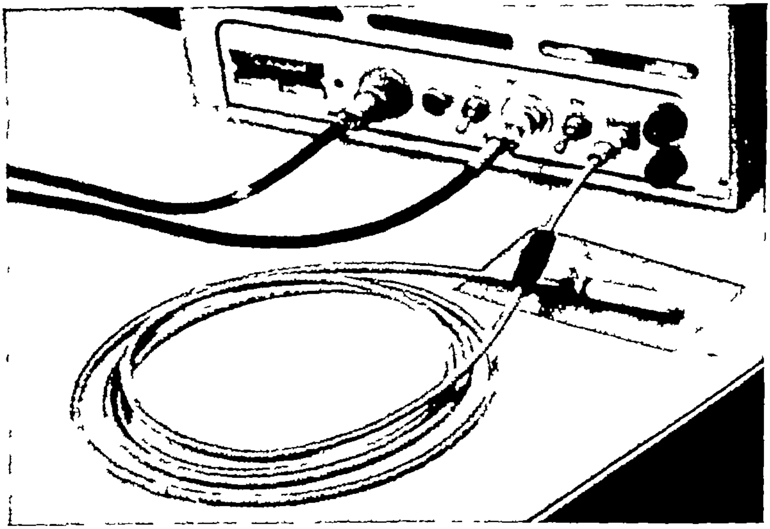

Fig 1 Pressure sensitive capsule cable and coil attached to the oscillator-amplifier

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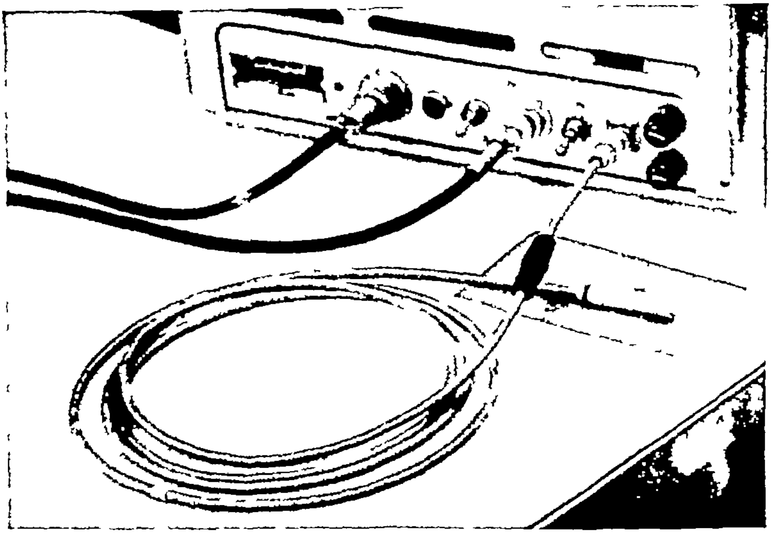

Fig 1 Pressure sensitive capsule cable and coil attached to the oscillator-amplifier

the two metallic surfaces separated by air come closer to each other, or move farther apart, as one is subjected to greater or less pressure than the other Aluminum foil was used for the metallic surfaces, but instead of air a thin sheet of rubber which forms a solid, flexible dielectric was employed to keep them apart The layers of foil and rubber were arranged concentrically to form a cylinder 1 cm in diameter and 5 cm long In order to record directly in a body cavity, rather than remotely as part of a gas or fluid filled system, a flexible water-tight cover protected the condenser from conducting solutions such as fluids in the esophagus, which could make a short circuit between the metallic surfaces

The capsule was mounted at one end of a coaxial cable,* 0.5 cm in diameter and 266 cm long, to permit insertion in the body cavity as well as attachment to an oscillator-amplifier. The coaxial cable is an important part of the arrangement, as it consists of a central wire separated from a braided shield in such a way that the spatial relationship of these two remains constant, and the capacitance of the cable varies as little as possible. Since cable and pressure capsule are part of the same electrical circuit, any variation in cable capacitance would simulate a change in capacitance of the pressure capsule and give a false indication of pressure change. The outer braided wire of the cable is attached to the grounded side of the electrical circuit, and, therefore, shields the inner wire from unwanted induced currents in the environment. Advantage is taken of this shielding effect when connecting the pressure capsule to the cable, as the outer of the two metallic surfaces of the condenser is attached to the outer braided wire of the cable.

In order to function properly the pressure sensitive capsule must be in series with a coil of just the right number of turns of No. 34 wire, so that together coil and variable condenser constitute a resonant circuit tuned to the oscillator or carrier frequency of the oscillator-amplifier system to which the cable is attached. A unique feature of the resonant circuit, as used in this case, is the separation of coil and pressure capsule. The coil is inserted in the cable at the end opposite to the pressure capsule, 9 cm from the connection to the oscillator-amplifier. This avoids placing the coil in a body cavity where it would be exposed to temperature and pressure changes that alter its inductance. Such changes in inductance would change the resonance of the circuit independently of the variable condenser, and produce unwanted deflections on the record not necessarily related to events occurring at the capsule end.

The oscillator-amplifier used† is similar in design to that described by Tomkins.[5] When the resonant circuit consisting of pressure capsule, coaxial cable and coil are attached to the input of this amplifier, they form one arm of an alternating current bridge which is balanced resistively but slightly unbalanced reactively. When the capacitance of the condenser varies, the reactive unbalance varies and the transmission of the bridge increases. The output voltage of the bridge is proportional to the reactive unbalance, and is changed in the amplifier circuit from an amplified radio-frequency signal to direct current. The pulsating direct current, an image of pressure change at the capsule is then used to drive the recorder, which in this case was a Sanborn Viso-Cardiette direct writer.

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*Belden No. 8447

†Manufactured by Technitrol Engineering Co., Philadelphia, Pa.

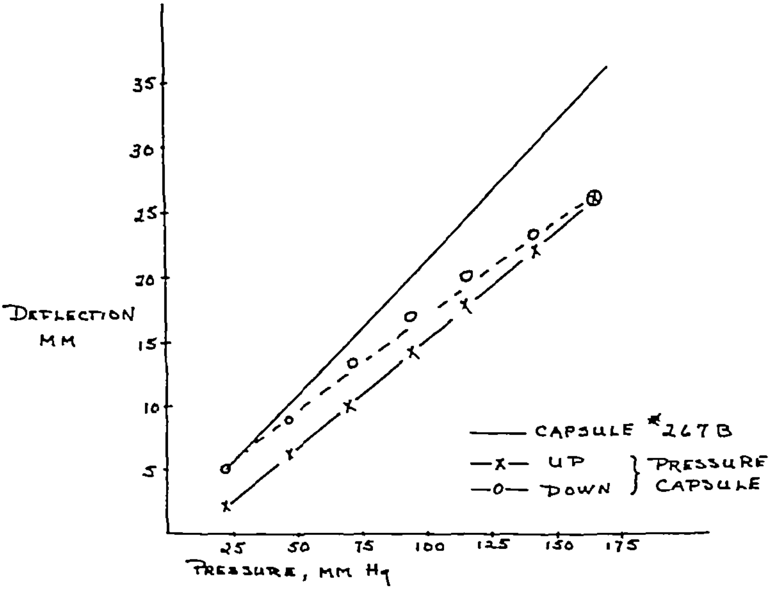

Fig. 2. Response to pressure change of the capsule described, compared to Sanborn capsule No. 267B

To determine whether it would follow pressure changes faithfully enough for the purposes of the experiment, a comparison of the performance of the capsule described was made with the Sanborn capsule No. 267B. This was accomplished by placing both capsules in the same air-filled system. The output of the oscillator-amplifier was fed into a DC coupling amplifier, which was one channel of a four channel recorder. The

Sanborn capsule was attached through its preamplifier to another channel of the same recorder The response of the Sanborn capsule was known to be linear, and the pressure of the system was varied in increments of 25 mm Hg as measured by the calibration of the Sanborn capsule The deflection in mm of the two capsules has been plotted against pressure, as shown in Fig 2, which indicated a fair linear response A good response to quick changes in pressure was observed when the pressure in the system was alternated two-and-a-half times a second

It is probable that the capsule could be made smaller, because of the inherent sensitivity of a radio-frequency device It may also be possible by further refinement in construction to increase the linearity of its response In addition to the application for which it was designed, there are other situations where it is desired to measure changes in intralumen pressure, and a transducer might have advantages Brody and Quigley compare various methods for recording these, and discusses their experience with them[2] One application which could be of considerable value, would be a direct recording of the response of bronchial musculature to various drugs

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INTERMITTENT PAROTID SWELLING DUE TO ILL-FITTING DENTURES—AN ENTITY, ITS DIAGNOSIS AND TREATMENT*†

A C FURSTENBERG, M D ,
and
IRVING M BLATT, M D ,‡
Ann Arbor, Mich

Renewed interest in sialography, with significant improvement in its technique during the past few years, has provoked many studies of salivary gland disease and a number of original observations Notable among these has been a better understanding of the etiology, diagnosis, and treatment of inflammatory conditions of the major salivary glands Sialography, the process of demonstrating roentgenographically the salivary duct system after the injection of radiopaque material, has given us valuable aid in the diagnosis and classification of obstructive and non-obstructive inflammatory lesions[1,2] Secretory sialography[3] clearly indicates that both conditions are responsible for characteristic changes in the anatomical configuration and physiological function of the major salivary glands

We have become particularly interested in one such obstructive phenomenon and its mode of management, namely, obstructive sialodochitis We believe it to be an entity due to an inflammatory stricture at the papilla of the duct developing as the result of trauma from improperly fitting partial or complete dentures This condition appears to have a natural history, recognizable clinical manifestations, diag-

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†From the Department of Otolaryngology University of Michigan Medical School Ann Arbor

‡Dr Irving M Blatt s present address is Department of Otolaryngology Wayne State University Detroit Michigan or Hanser Clinic 7411 Third Ave Detroit 2 Michigan.

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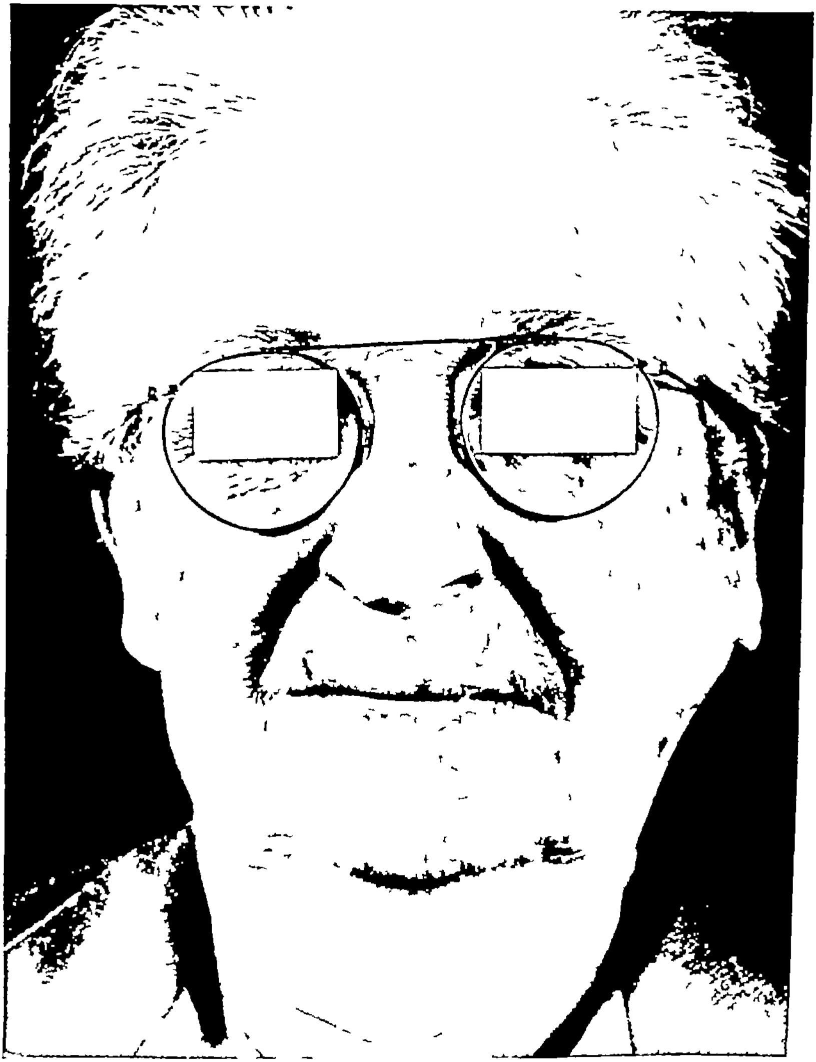

Fig 1 Case 1 Unilateral inflammatory cyst of the parotid gland

nostic radiographic features, and definite histopathologic changes

Until recently the management of this condition has consisted of frequent duct dilatations and the administration of antibiotics and chemotherapeutic agents for the relief of swelling and pain incident to the inflammatory reaction within the gland We should like, therefore, to describe the diagnostic features and pathogenesis of this condition, and to offer a simple operative procedure for its alleviation

PRESENTATION OF CASES

Case 1 G A. No 781775, a 72 year-old widow was admitted to University Hospital on April 22, 1954, for evaluation and treatment of a left parotid swelling of eight months duration the enlargement was noticed for the first time after eating There was pain characterized by 'a festering ache and a ropy feeling' in the left cheek. Over a four week interval the swelling did not recede completely but fluctuated at meal times between the size of a 'kernel and large lima bean" The size of the parotid mass remained stationary for three months prior to admission

The patient had been wearing complete dentures for more than 30 years Six years prior to admission she noticed that the upper dentures became increasingly mobile and often embarrassed her by falling upon the lower lip when opening the mouth this was also troublesome during mastication Various cements' were used in an effort to hold the upper plate in position

Physical examination revealed a 3x4 cm mass in the posteromedial portion of the left parotid gland which transmitted light (see Fig 1) The remainder of the parotid gland was diffusely palpable but not nodular When the mouth was opened the upper denture fell on the lower lip There was considerable front to rear and side to side movement of the upper denture. The parotid papilla on each side was hypertrophic and rigid Stensen's duct orifice was patent, and the duct, which was cord like was palpable throughout its buccal course Pressure over the gland gave rise to a profuse flow of clear saliva without an immediate return of parotid swelling Lemon stimulation produced a similar condition A size No 1 olive-tipped probe inserted into the duct revealed a fusiform stenosis 0 5 cm from the orifice At this point the wall of the duct imparted a gritty sensation There were no additional strictures in the bucco-masseteric course of Stensen's duct. On the contrary, the duct felt diffusely dilated Further dilation of the duct orifice preparatory to sialography promoted an active flow of saliva with lemon stimulation

A smear of the saliva collected by polyethylene catheterization failed to reveal any cells organisms or crystalline material The culture yielded organisms of the non pathogenic actinomyces species which were considered contaminants The total volume of parotid saliva secreted by continuous lemon stimulation after overnight fasting and collected by polyethylene catheterization was 16 4 c c in 60 minutes (see Table I)

Films of the left parotid sialogram taken after injection of 1 0 c c of Pantopaque showed elongation tortuosity and dilation of Stensen s duct without evidence of stricture in its bucco-masseteric course (see Fig 2) This was accompanied by displacement of the secondary and tertiary ducts about a space-occupying lesion within the left parotid gland There was minimal retention of contrast material on the post-evacuation films This sialographic picture was compatible with an inflammatory cyst and chronic main duct obstruction Aspiration of 17 c c of fluid was followed by injection of an equivalent amount of 30 per cent Urokon to outline the cyst cavity (see Fig 2)

A subtotal parotidectomy was performed with excision of the cyst

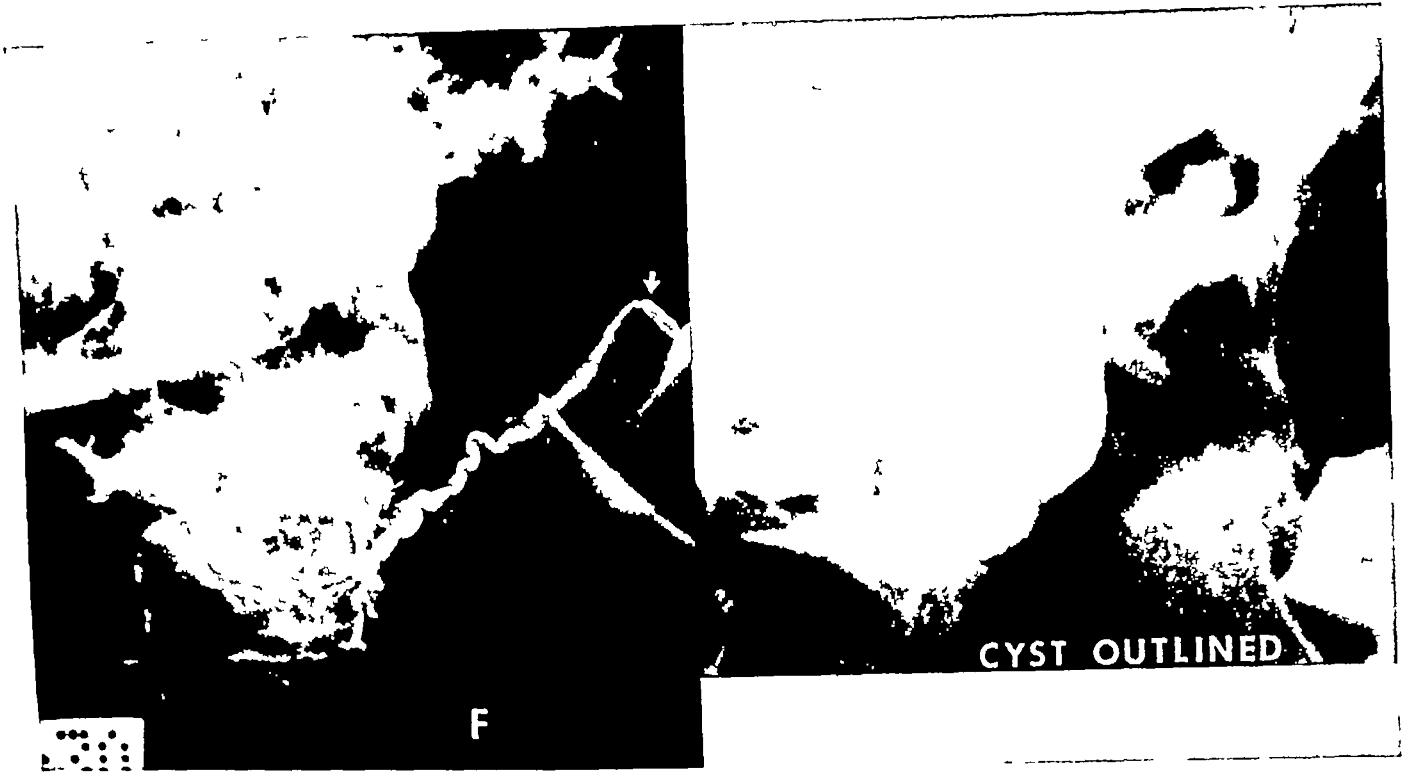

Fig 2 Sialogram of an inflammatory cyst associated with main duct obstruction
The Filling Phase shows elongation tortuosity and dilation of Stensen's duct with evidence of stricture at the orifice only The stricture has been widely dilated at the arrow Aspiration of 17 c c of fluid followed by injection of an equivalent amount of 30 per cent Urokon to outline the cavity of the cyst

There was considerable scar tissue in the wall of the cyst with evidence of chronic inflammation in the salivary gland (see Fig 3)

Case 2 K. S No 875192 a 58 year-old housewife was admitted to University Hospital on July 9 1957 with painful bilateral swelling of the parotid gland The patient was well until April, 1942, when suddenly she noted painful right parotid swelling while eating A diagnosis of mumps was made by the family physician Subsequent episodes occurred approximately every three months, all associated with eating In October, 1946 the left parotid gland was similarly involved

In 1938 upper and lower complete dentures had been made for the patient but they did not seem to fit satisfactorily During the ensuing years other dentures were provided but they never were entirely satisfactory for mastication

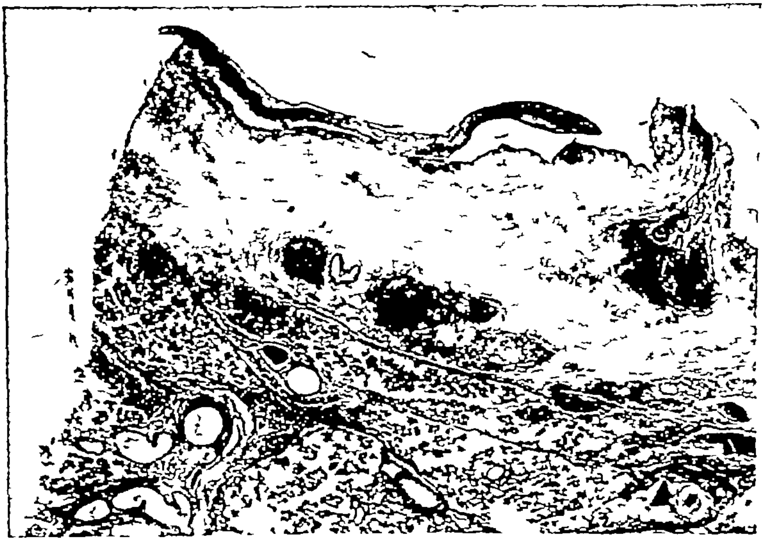

Fig 3 Case 1 The microscopic section shows considerable scar tissue in the wall of the cyst with chronic inflammation.

Physical examination revealed bilateral diffuse parotid enlargement (see Fig 4) The upper denture fell upon the lower lip when the mouth was opened The lower denture had considerable anteroposterior mobility and was observed to override each caruncula salivaris at the site where the submaxillary duct (Wharton's duct) opens into the floor of the mouth Both parotid papillae were hypertrophic and scarred The salivary flow from each parotid gland was sluggish Upon stimulation of salivary secretions by sucking a lemon slice the face swelled gradually, and the flow of saliva into the mouth came in spurts Probing of each Stensen s duct revealed a stricture at the duct orifices as well as additional strictures along the bucco-masseteric course of Stensen s duct. The wall of each Stensen s duct imparted a gritty sensation upon probing There were no strictures in either submaxillary (Wharton s) duct

A smear of parotid saliva collected by polyethylene catheterization revealed desquamated cuboidal epithelial cells No organisms were observed by smear or culture from either side The submaxillary saliva showed no cells or organisms Total volume of parotid saliva secreted by continuous lemon stimulation after overnight fasting was 17 7 c c in 60 minutes for the right parotid gland and 18 1 c c in 60 minutes for the left (see Table I) A quadriglandular sialogram was performed An injection of 0 9 c c of Pantopaque in each Stensen's duct revealed a markedly dilated and irregularly segmented main duct The submaxillary ducts (0 35 c c Pantopaque injected in each duct) were similarly involved although the degree of dilation was not so pronounced as in the case of Stensen s ducts (see Fig 5)

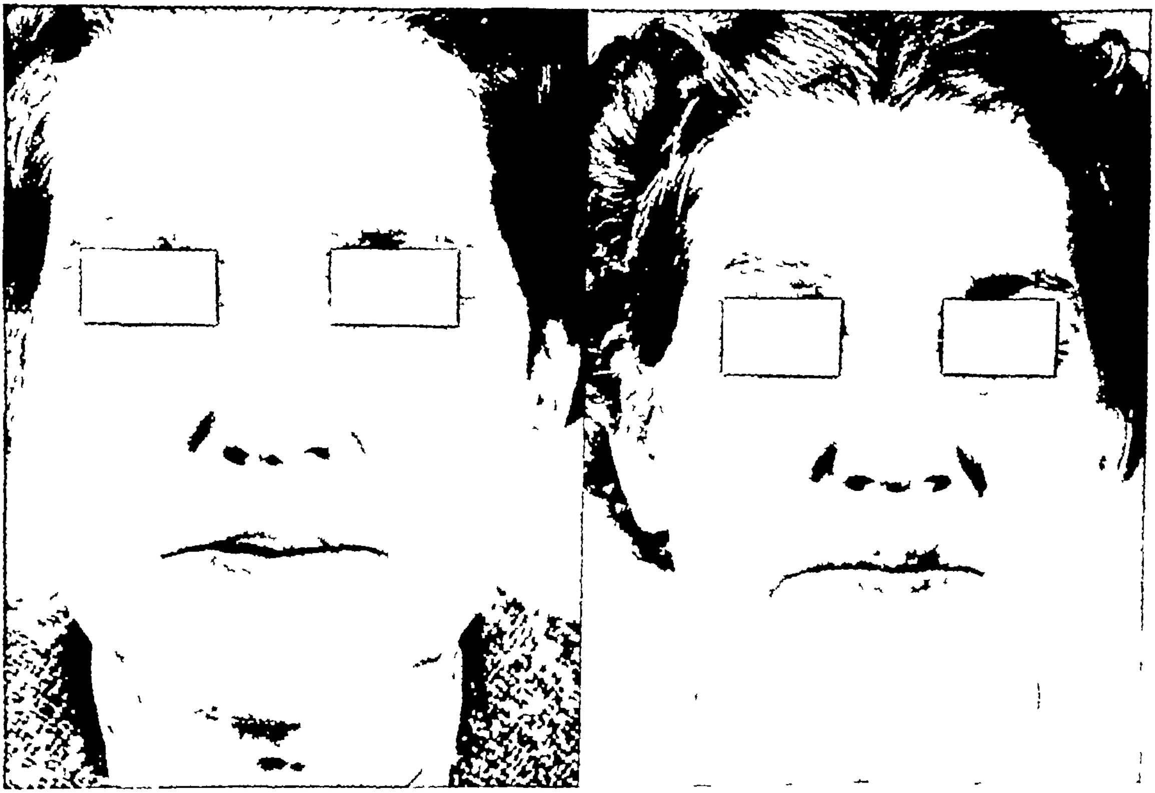

Fig 4 Case 2 Photographs taken before and one week after bilateral parotid dochoplasty

On July 16 1957 a bilateral dochoplasty of Stensen s duct was performed

Case 3 M B No 839162 A 46 year old wife of a physician came to University Hospital in April 1956 because of repeated painful swellings of the left parotid gland This patient had been asymptomatic until May 1955 when she noted a sudden post prandial left parotid swelling This was associated with a low grade fever Subsequently she complained of a feeling of tightness and dull pain in the bucco masseteric region while eating The diagnosis of mumps was made at the time of the original attack. During the next ten months there were similar episodes of pain and swelling in the left parotid area approximately once a month and invariably associated with her meals The swelling receded spontaneously on each occasion

Upper and lower partial dentures had been made for this patient in 1944 for the purpose of correcting her bite She stated that the upper dentures became loose frequently and had to be 'tightened" She preferred to chew her food on the right side

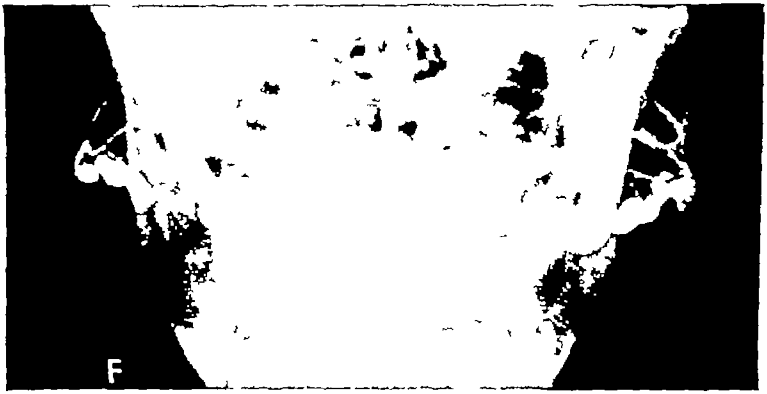

Fig 5 Sialogram of advanced main duct obstruction with secondary infection The Filling Phase reveals that each Stensen's duct is markedly dilated and irregularly segmented.

Physical examination revealed a moderately swollen diffusely palpable left parotid gland The left parotid papilla was hypertrophic A scanty amount of clear gelatinous saliva could be milked from the duct orifice Upon stimulation by sucking a lemon slice the left parotid gland swelled and a firm ropy Stensen's duct could be palpated along its bucco-masseteric course Upon further milking of the duct system by massage saliva entered the mouth with a squirt. Probing revealed a stricture 0 5 cm proximal to the duct orifice and only a size No 1 olive-tipped probe could be passed beyond the stricture Additional strictures were also encountered along the bucco masseteric course of Stensen's duct The wall of the duct imparted a gritty sensation upon probing The saliva contained desquamated cuboidal cells but no organisms were found in the smear or culture The total volume of parotid saliva secreted by continuous lemon stimulation (after overnight fasting) was 20 5 c c in 1 hr on the left side and 20 0 c c. in 1 hr on the right (see Table I) This secretion was obtained after the stricture near the orifice had been widely dilated

The sialogram revealed multiple strictures of Stensen's duct on the left side after injection of 0 8 c.c Pantopaque There was virtually complete retention of the contrast material on the five-minute post-evacuation film (see Fig 6) The filling and excretory films of the right parotid gland and submaxillary glands were normal

On June 15 1956 a dochoplasty was performed

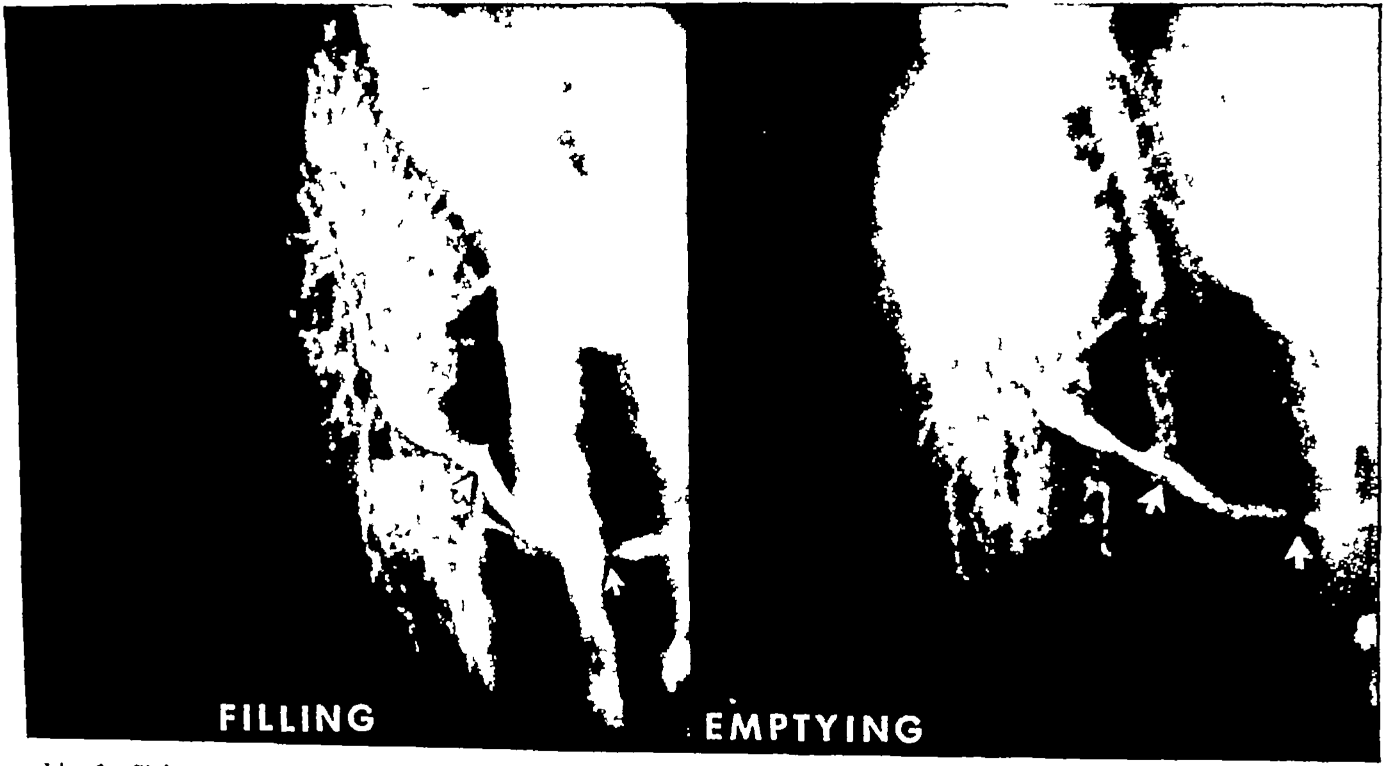

Fig. 6 Sialogram of uniform dilation of Stensen's duct with beading (2X enlarged) This appears to be an early anatomic alteration characterized by stricture formation (arrows) at the duct orifice and along the bucco-masseteric course of Stensen's duct In the 5-Minute Post-Evacuation Film the obstruction to salivary flow is verified by the unaltered appearance of the sialogram

THE CLINICAL PICTURE

As noted by other investigators,[4,5] the condition is associated with partial or complete dentures which are ill-fitting Diffuse parotid swelling with pain and a feeling of pressure in the cheek frequently occurs while eating When salivary flow is stimulated by a potent sialogogue (lemon) the gland may swell Upon massage of the parotid region, only a sluggish flow of clear saliva from a hypertrophic parotid papilla is noted The cord-like dilated Stensen's duct can usually be palpated along its bucco-masseteric course Upon probing the duct, dilated segments alternate with strictures A gritty sensation imparted to the probe by the hypertrophic and metaplastic duct epithelium (see Fig 9) may be mistaken for calcareous material

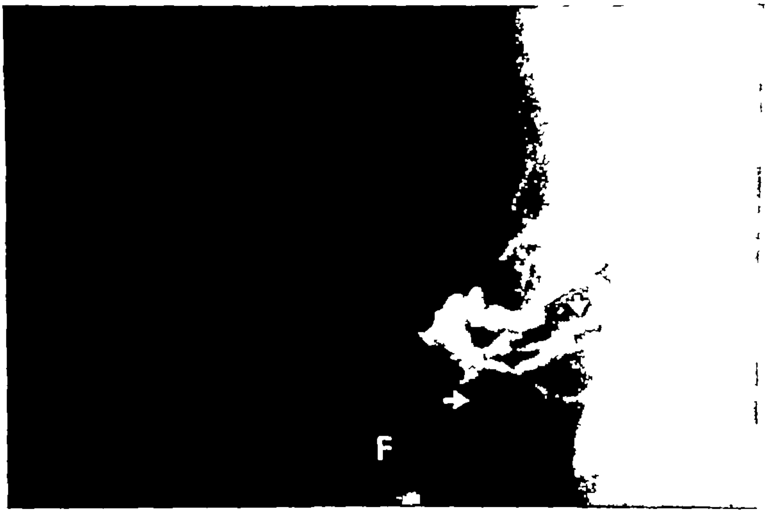

Fig 7 Case 2 A sialogram of the Filling Phase (2X enlarged) demonstrates that the secondary ducts (arrows) may also be involved in obstructive sialodochitis however there is no alteration of the most peripheral radicals This is the differential point between obstructive sialodochitis and non-obstructive sialectasis

THE PATHOGENESIS

This condition appears definitely to be associated with the

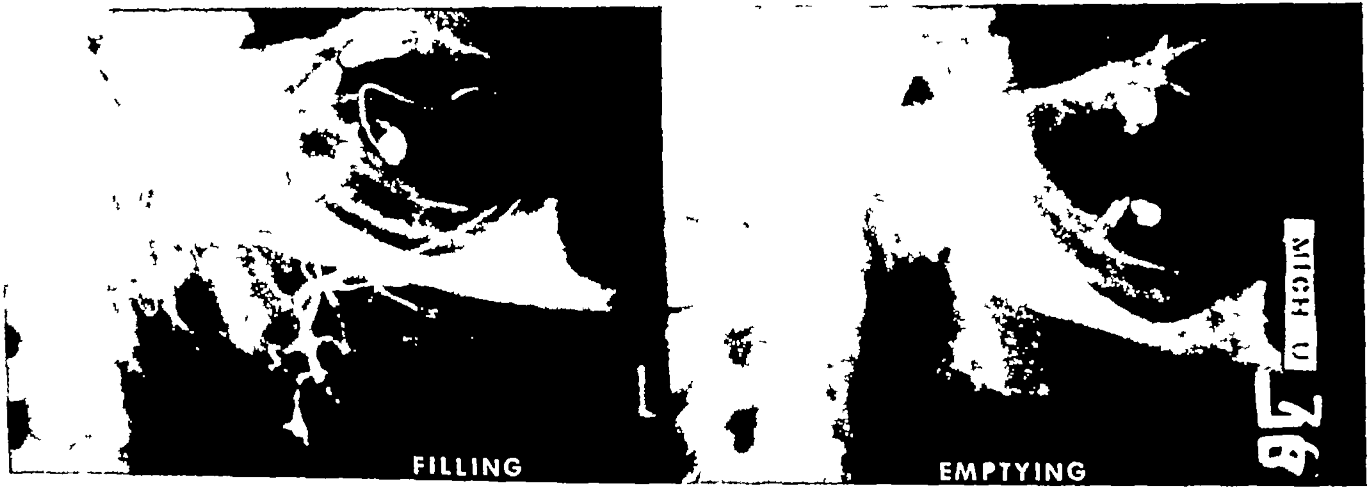

Fig 8 Case 2 The Filling Phase of this quadriglandular sialogram demonstrates the markedly dilated and irregularly segmented main ducts (Stensen s ducts) The submaxillary ducts (Wharton s ducts) can be similarly involved though the degree of dilation is not so pronounced There is no alteration of the peripheral duct architecture The Post-Evacuation Film indicates that the obstruction at the outlet (orifice) is the principal deterrent to evacuation

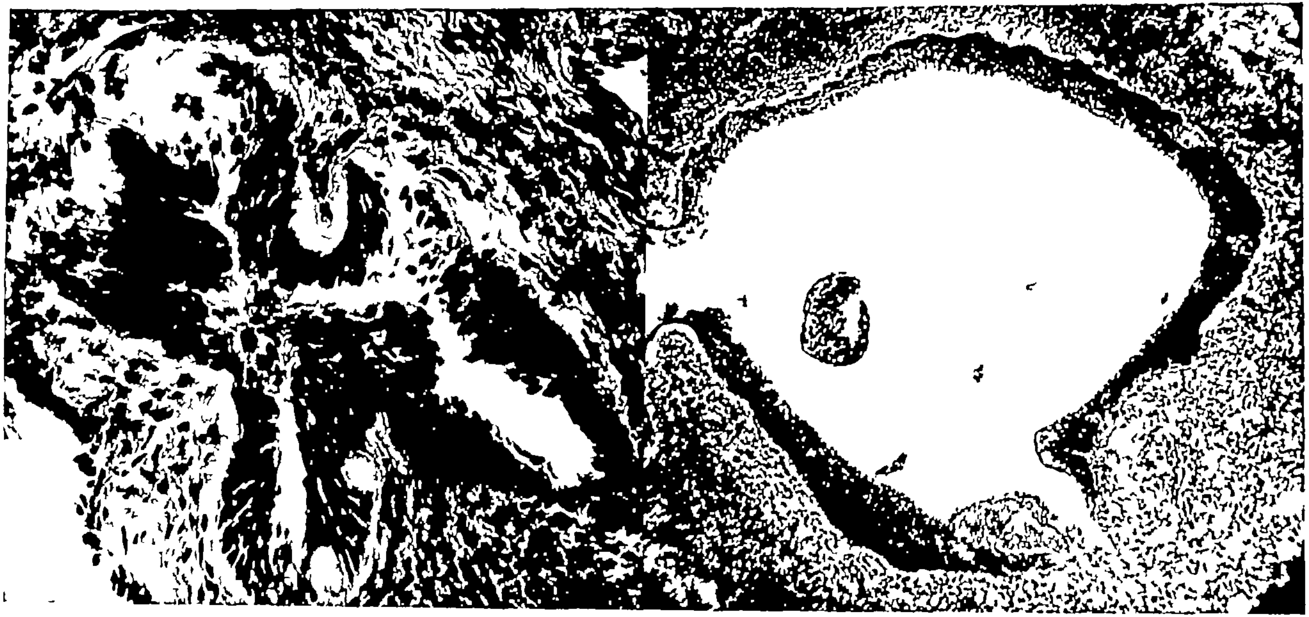

Fig 9 Case 2 Microscopic sections taken from (A) the constricted orifice of Stensen s duct (B) the greatly dilated portion of the main duct just proximal to the stricture There is metaplasia scar tissue formation and stenosis at the site of the stricture This is consequent upon traumatization of Stensen s duct orifice in the parotid papilla

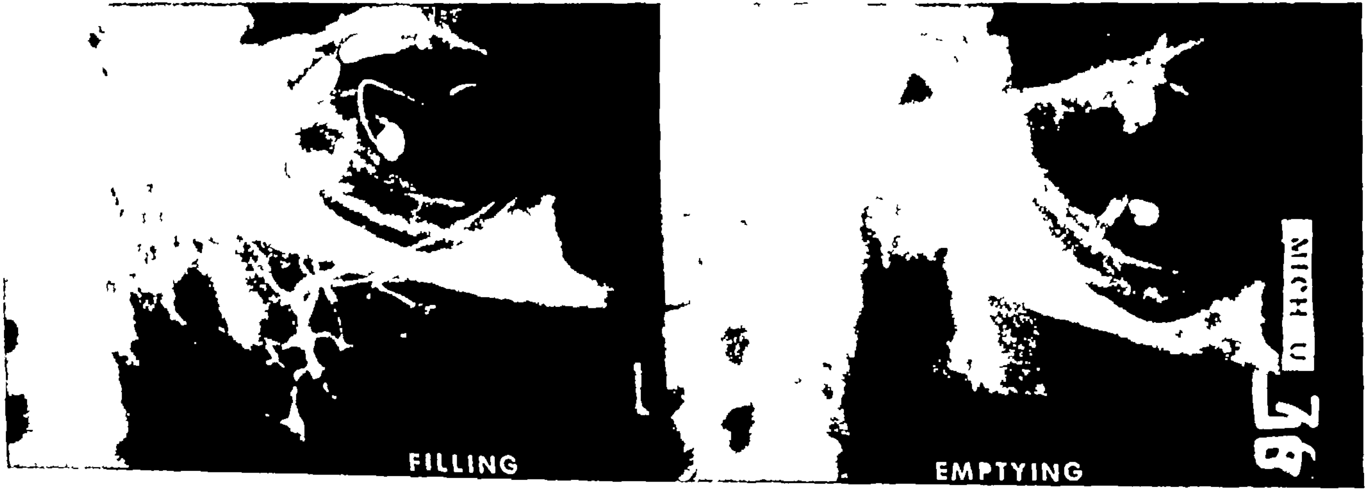

Fig 8 Case 2 The Filling Phase of this quadriglandular sialogram demonstrates the markedly dilated and irregularly segmented main ducts (Stensen s ducts) The submaxillary ducts (Wharton s ducts) can be similarly involved though the degree of dilation is not so pronounced There is no alteration of the peripheral duct architecture The Post-Evacuation Film indicates that the obstruction at the outlet (orifice) is the principal deterrent to evacuation

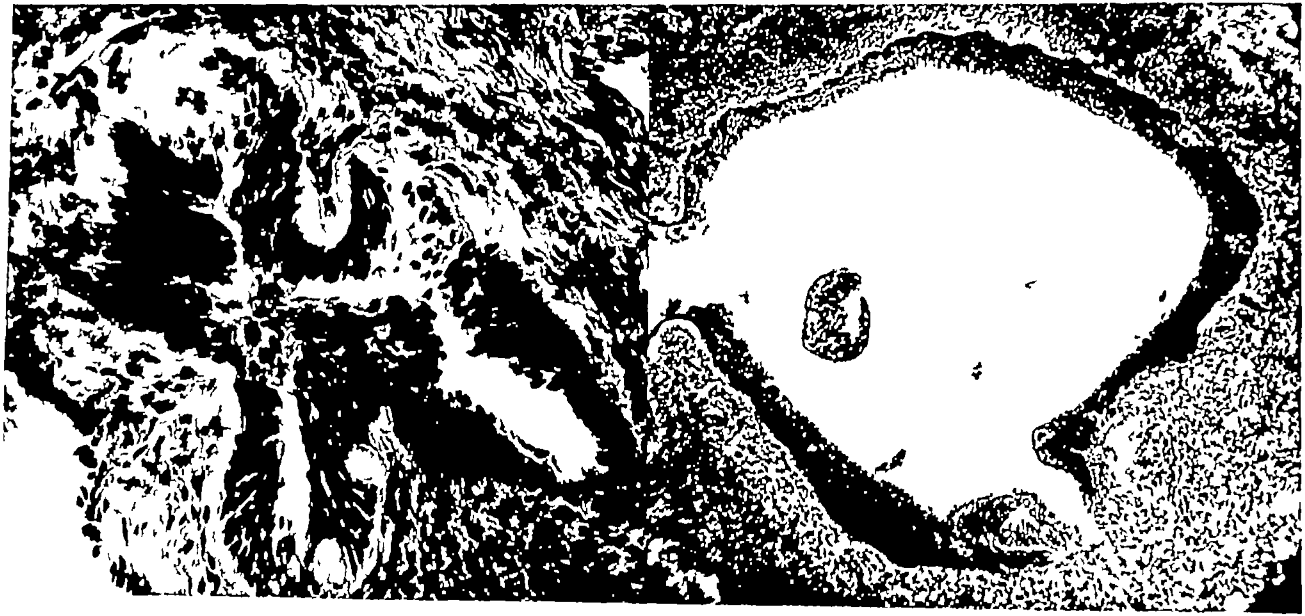

Fig 9 Case 2 Microscopic sections taken from (A) the constricted orifice of Stensen's duct (B) the greatly dilated portion of the main duct just proximal to the stricture There is *metaplasia* scar tissue formation and stenosis at the site of the stricture This is consequent upon traumatization of Stensen's duct orifice in the parotid papilla

presence of dentures The patient is required to alter the mechanism of mastication in a manner which does not sustain the normal chewing habit As food is being chewed on one side of the mouth, the parotid papilla on the opposite side tends to be sucked mesially and bitten Mastication is further rearranged and altered when alveolar absorption occurs, allowing the dentures to shift about while chewing

When the parotid papilla is subjected to repeated trauma and inflammation, fibrous tissue proliferation and scar tissue cicatrization occur This interferes with normal salivary flow, and the ensuing pressure behind the stricture results in dilatation of the gland duct It is not long before secondary bacterial infection supervenes with a diffuse inflammatory reaction along the bucco-masseteric course of Stensen's duct and with production of multiple inflammatory strictures If a stricture in the secondary or tertiary ducts seals off a section of secreting acinar tissue an inflammatory cyst may be formed (see Fig 2)

THE SIALOGRAM WITH CLINICAL AND HISTOLOGICAL CORRELATION

The diagnostic features of this condition are dilatation and stricture formation in the main salivary duct *without the terminal peripheral duct involvement* seen in sialectasis The degree of anatomic alteration depends on the frequency, severity and duration of *1* Obstruction caused by injury to the parotid papilla, *2* Secondary bacterial infection associated with interference of salivary flow

Among the patients above described, three roentgenographic patterns can be distinguished

1 ELONGATION, TORTUOSITY AND DILATATION OF THE MAIN DUCT

These changes are noted when a stricture is present near the duct orifice (see Fig 2) Filling phase films and probing demonstrated the stricture Some of the secondary and tertiary radicals share in the dilatation If a stricture in the minor ducts resulting from a parotid infection seals off a section of secreting acini an inflammatory cyst may be formed A monolocular cyst with considerable scar tissue in its wall and with surrounding parenchymal pressure atrophy is seen in Fig 3 The stricture was probably the result of a parotitis eight months prior to admission to the hospital, the only such episode experienced by the patient

2 UNIFORM DILATATION OF STENSEN'S DUCT WITH BEADING

This appears to be an early anatomic alteration of the duct characterized by stricture formation at its orifice and along its bucco-masseteric course We note these changes in Stensen's duct of patient (Case 3) The emptying film shows virtually complete retention of the contrast material (see Fig 6) The mechanism of retention is no doubt related to the checking action of the salivary flow by multiple strictures along the course of the duct and the non-distensible stricture at the duct orifice

3 MARKED DILATATION AND IRREGULAR SEGMENTATION OF THE MAIN DUCT

These changes are seen in patient (Case 2), in whom ill-fitting dentures were worn for 19 years, with recurrent episodes of parotid swelling As noted in the filling phase, the secondary ducts are also involved, but the most peripheral radicals do not participate in the inflammatory process (see Fig 7) This represents an advanced composite picture of main duct obstruction and secondary bacterial infection The submaxillary ducts can be similarly involved if the lower denture is faulty, although the degree of dilatation is not pronounced The post-evacuation film demonstrates that the obstruction at the outlet is the principal deterrent to evacuation (see Fig 8) When the stenotic duct orifices are removed surgically and a duct-plasty is performed, the continuous flow of saliva is re-established and the parotid swelling recedes Histologic sections of the constricted duct orifice show metaplasia, scar formation and stenosis that are the result of trauma of Stensen's duct in the parotid papilla (see Fig 9)

DISCUSSION

Obstructive sialodochitis due to ill-fitting dentures is not a common disorder when compared with salivary gland inflammation caused by calculi or by the non-obstructive sialodochiectasis (sialectasis) group of diseases such as recurrent pyogenic parotitis, Sjogren's syndrome and Mikulicz disease Only three such cases (2 7 per cent) have been observed in a total of 138 patients referred to the clinic for various inflammatory lesions of the salivary glands since July, 1953 These cases also represent only 0 75 per cent of 352 sialograms made since the above date Because of the morphologic pattern of main duct "estasia" produced by alternating dilatations and strictures, the condition belongs to the obstructive sialodochiectasis group as classified by various investigators[1,4,7], however, obstructive sialodochitis should not be confused with non-obstructive sialectasis In the former, there is no alteration in the terminal ducts nor diminuation in the volume of saliva secreted[8] In the latter, however, we note dilatation of many of the terminal ducts, and a definite diminution in the quantity of saliva secreted by the diseased gland

TABLE I—SECRETION VOLUME STUDIES OF PURE PAROTID SALIVA IN C C/HR

Method of Collection	Stimulation Feeding	Via Polyethylene Catheter Continuous Lemon Slices			
Normal Female Age 44	21 c c	Case 3	Age 46	20 5 c c 20 0 c c	Left Parotid, Right Parotid
Normal Female, Age 60	17 5 c c	Case 2	Age 58	17 7 c c 18 1 c c	Right Parotid, Left Parotid
Normal Female, Age 70	17 0 c c	Case 1	Age 72	16 4 c c	Left Parotid

In obstructive sialodochitis, associated with ill-fitting dentures, the volume of pure parotid saliva secreted in c c per hr does not appear to vary from the normal (see Table I), and this probably explains the normal architectural pattern of the terminal ducts seen roentgenographically Possibly, too, it accounts for the fact that no pyogens or inflammatory cells are present Thus, the mechanism which resists retrograde infection of salivary parenchyma by mouth organisms[6] can operate successfully in the face of increased pressure gradients of dilatation and strictures, as long as the normal complement of acinar tissue is available and sufficiently productive to wash the organisms out of the duct

Anatomically, two types of duct obstruction are apparently produced—that which is noted at the duct orifice and obstruction along the bucco-masseteric course of the duct The duct orifice obstruction is caused by trauma to the parotid papilla The bucco-masseteric obstruction appears to be a more advanced stage of the condition resulting from secondary basterial infection and inflammatory reaction along the bucco-masseteric course of Stensen's duct

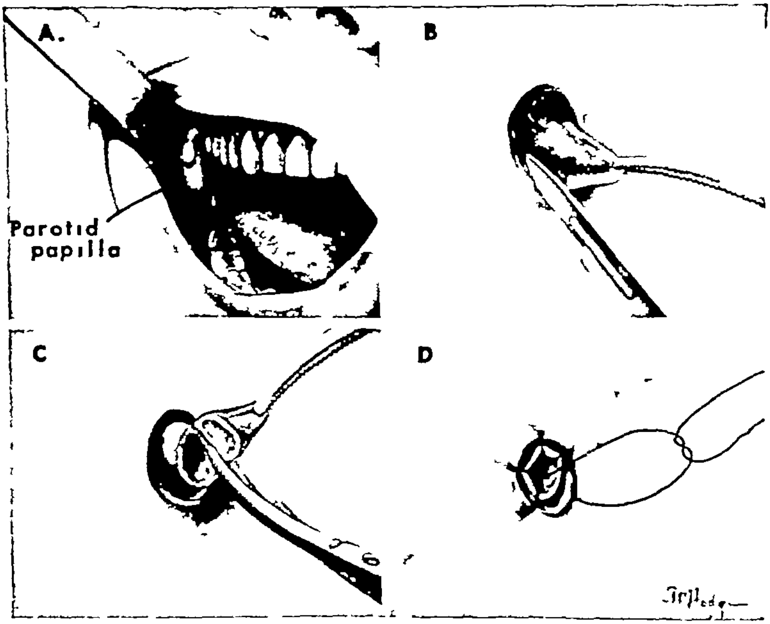

Fig 10 Technique of Dochoplasty A—Parotid papilla opposite second molar tooth. B—The parotid papilla is grasped and the stenotic portion of Stenson's duct is dissected free from the surrounding buccal tissue C—The papilla is amputated D—The open end of the duct is sutured with fine silk to the surrounding mucous membrane

TREATMENT

The treatment is surgical The technique of dochoplasty is

DISCUSSION

Obstructive sialodochitis due to ill-fitting dentures is not a common disorder when compared with salivary gland inflammation caused by calculi or by the non-obstructive sialodochiectasis (sialectasis) group of diseases such as recurrent pyogenic parotitis, Sjogren's syndrome and Mikulicz disease. Only three such cases (2.7 per cent) have been observed in a total of 138 patients referred to the clinic for various inflammatory lesions of the salivary glands since July, 1953. These cases also represent only 0.75 per cent of 352 sialograms made since the above date. Because of the morphologic pattern of main duct "estasia" produced by alternating dilatations and strictures, the condition belongs to the obstructive sialodochiectasis group as classified by various investigators[1,4,7], however, obstructive sialodochitis should not be confused with non-obstructive sialectasis. In the former, there is no alteration in the terminal ducts nor diminuation in the volume of saliva secreted.[8] In the latter, however, we note dilatation of many of the terminal ducts, and a definite diminution in the quantity of saliva secreted by the diseased gland.

TABLE I—SECRETION VOLUME STUDIES OF PURE PAROTID SALIVA IN C.C./HR.

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	Stimulation Feeding	Continuous Lemon Slices			
Normal Female, Age 44	21 c.c.	Case 3	Age 46	20.5 c.c. 20.0 c.c.	Left Parotid, Right Parotid
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Normal Female, Age 70	17.0 c.c.	Case 1	Age 72	16.4 c.c.	Left Parotid

In obstructive sialodochitis, associated with ill-fitting dentures, the volume of pure parotid saliva secreted in c.c. per hr. does not appear to vary from the normal (see Table I), and this probably explains the normal architectural pattern of the terminal ducts seen roentgenographically. Possibly, too, it accounts for the fact that no pyogens or inflammatory cells are present. Thus, the mechanism which resists retrograde infection of salivary parenchyma by mouth organisms[6] can operate successfully in the face of increased pressure gradients

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GRANT TO JEWISH HOSPITAL, ST LOUIS

The receipt of a $5,000 grant from the Louis D Beaumont Foundation for the furtherance of research in the field of surgical rehabilitation of hearing at the Jewish Hospital of Saint Louis was announced recently by Dr Ben H Senturia, Director of the Department of Otolaryngology The check was presented to the Hospital by Mr Morton J May, Trustee of the Foundation

The surgical rehabilitation program is a recently expanded one, functioning on both clinical and research levels It includes comprehensive pre- and post-operative hearing testing, an evaluation of the function of the Eustachian tube, and surgical correction of the pathologic changes which involve the ear drum, ossicular chain and middle ear simple enough Under local anesthesia (procaine 1 per cent) injected about the orifice of Stensen's duct, the papilla is grasped and amputated (see Fig 10) This simple procedure exposes the stenotic duct, which is then dissected free from the surrounding tissue for a distance usually of something less than a centimeter until its dilated portion is identified At this point the duct stands out conspicuously because of its marked dilation The open end of the duct is then sutured, with fine silk, to the surrounding mucous membrane in a manner which exposes the duct to free communication with the oral cavity

Antibiotics and chemotherapeutic agents may be used for several days postoperatively Healing is kindly and prompt Rapid regression of parotid swelling occurred in the three patients herein reported, and they have remained asymptomatic to date

SUMMARY

1 Ill-fitting dentures can cause the syndrome of obstructive sialodochitis with intermittent parotid swelling We believe it can be regarded a definite entity

2 The pathogenesis and clinical picture are presented with radiographic and histologic correlation

3 Secretory sialography is useful in making the diagnosis and in differentiating it from non-obstructive sialectasis

The histologic picture is that of stenosis, scar tissue formation, and metaplasia of the duct epithelium, all compatible with traumatization of the parotid papilla

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a congenital disease in which the basic difficulty is an inborn error of metabolism transmitted as a sex-linked recessive trait demonstrable clinically only in males, *second*, an acquired form of agammaglobulinemia which occurs in either sex and has its onset at any age, *third* an extension of the neonatal agammaglobulinemia beyond the time at which normal production ordinarily begins In these cases, he finds a generalized absence of lymphoid tissue including tonsils and adenoids, with the lives of the patients a constant succession of bacterial infection, most frequently encountered as chronic lung disease, sinusitis, otitis media, pharyngitis and occasionally either a sprue-like syndrome or recurrent bacterial meningitis

It occurred to us that in studying clinical patients, instead of studying the agammaglobulinemic, much could be learned from the patient with hypogammaglobulinemia Electrophoretic patterns were performed on 126 patients with chronic recurrent infections, which would respond temporarily to antibiotics but would recur when they were stopped In an effort to keep the results practical, the tests were made at easily available commercial laboratories rather than by our own highly specialized technicians, for while this might diminish the accuracy slightly, it would provide a tool available to most physicians The results fell into three main categories the first, consisted of 58 patients who had normal Gammaglobulin levels, the second group of 24 patients, chiefly Navajo Indians, in which there was a marked increase in Gammaglobulin, and the third group of 44 people in which there was a deficiency This is a study of these cases which had at least a 40 to 50 per cent deficiency

Twenty-one patients of ours fall into the deficiency classification Five have been reported previously[3] Of the 16 subsequently found, 13 suffered with chronic pharyngitis, having large, raised plaques of lymphoid tissue in the pharynx and nasopharynx, and slight to moderate glandular adenopathy of the cervical chain Of the remaining, two patients had chronic draining ears, and the last, a sinus infection

One of the ear problems had been subjected to a mastoidec-

EFFECT OF HORMONES ON HYPOGAMMAGLOBULINEMIA *†‡

DAVID A DOLOWITZ, M D ,
THOMAS F DOUGHERTY, Ph D , (By Invitation),
and
ROBERT D HIGGINBOTHAM, Ph D , (By Invitation),
Salt Lake City, Utah

A deficiency of gammaglobulin is found in certain cases of chronic upper respiratory infection Often, this type of problem case will improve while being given the appropriate antibiotic, only to regress into the chronic ailment when such medication is stopped It has been known that Gammaglobulin, given parenterally, will give protection for periods of three to four weeks This is a report of studies to see whether thyroid and steroid hormones can bring the Gammaglobulin back to more normal levels with relief of the infection

Recently, Good[1] studied "Experiments of Nature" to see whether an understanding of the mechanisms of antibody and Gammaglobulin production can be found by studying the characteristics and adjustment of tissues in patients suffering from extreme disturbances of the immunological mechanism

His work centered chiefly on agammaglobulinemia which he feels has four cardinal features *1* Increased susceptibility to infection, *2* Absence of Gammaglobulin from the blood and tissues, *3* Absence of circulating antibody from the blood and tissues, *4* Failure of antibody production in response to antigenic stimulation

He recognizes three forms of this disease *First*, Bruton's,[2]

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*Read at the meeting of the Western Section American Laryngological Rhinological and Otological Society Beverly Hills Calif Jan 18 1958

†From the Department of Surgery and Anatomy University of Utah Medical School the Memorial Medical Center and the Holy Cross Hospital Salt Lake City Utah

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the pituitary, might also increase Gammaglobulin production It was realized that profound changes in resistance are not necessarily associated with either hypo- or hyper-thyroidism, but dysfunction of the thyroid has been related to resistance through the above mentioned mechanisms Since the thyroxine has been reported to increase opsonin production,[6 7] it was felt that an iodine-containing portion of thyroid secretion would be the most desirable to use

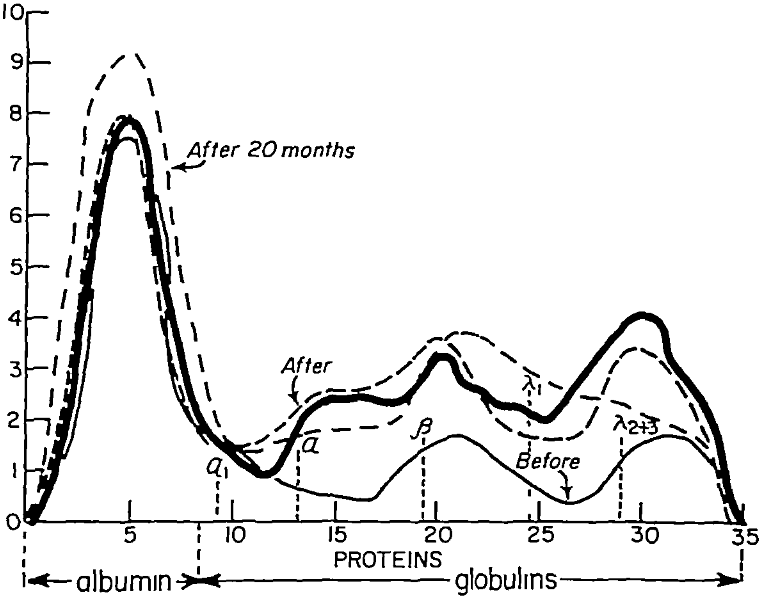

Fig 1

Sodium liothyronine (Cytomel*) was thought to be the most desirable iodine containing thyroid extract for the study Its action[8] is believed to be directly on the peripheral tissues, and immediate results could be expected without awaiting intermediate metabolic conversions It is effective in some cases where other thyroid hormones fail In addition, because of its rapidity of onset of action, symptoms of overdose would be recognizable promptly enough for safe withtomy twice, once in the Service 14 years ago, and a second radical operation three years ago Despite the surgery, the ear continued to drain and granulations kept forming very rapidly, resisting all attempts to remove them One antibiotic after another was used without benefit until the organism (Pseudomonas Aeruginosa) developed resistance An electrophoretic pattern of serum proteins demonstrated the suspected deficiency He was given 10 cc of Gammaglobulin intramuscularly every four weeks, the appropriate dosage for his weight This treatment has continued for a period of nine months The ear has dried during this time, and the granulations are slowly disappearing He is being treated with the appropriate antibiotic in addition to this therapy, but while there were no results on the antibiotic alone, the Gammaglobulin plus the antibiotic has so far been quite successful It is interesting to note that electrophoretic studies still show the same deficiency present as existed when the therapy was started, despite the clinical improvement

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*The Cytomel was generously supplied by Mr John Simon of Smith Kline & French Laboratories Philadelphia Pa

As reported a year ago,[3] it was found that when the antibodies were not being adequately secreted, steroids might allow the cells, lymphocytes and/or plasma cells to "secrete" retained Gammaglobulin

Of the five cases reported, one has not returned Three are well clinically after receiving Meticortelone, 25 mgms intramuscularly every three weeks for several months They now return only periodically for check-up The fifth is still under treatment, and still reports for 25 mgms of prednisolone intramuscularly every month As long as he has this he is free of sore throat, but on the three occasions when he has omitted the treatment, the pharyngitis returned, though less severely The electrophoretic pattern still shows a definite Gammaglobulin loss, but it is slowly returning to normal, and the lymphoid hyperplasia is clearing (see Fig 1)

It occurred to us that since thyroid produced an increased lymphocytosis[4] followed by a later parallel mononuclear production, and increased protein metabolism, it might increase the circulating Gammaglobulin It also was possible that small doses of thyroid, which would enhance steroid production via

Since that time he has been given one dose of ten micrograms of Cytomel for four days, every three weeks As long as this is taken, his ear remains dry With colds, he is given an appropriate prophylactic antibiotic Although it is realized that this will not affect the Proteus, it is believed this will keep down the coccal forms which may allow the Proteus to start spreading With this combination his infection has been kept under control for the past eight months

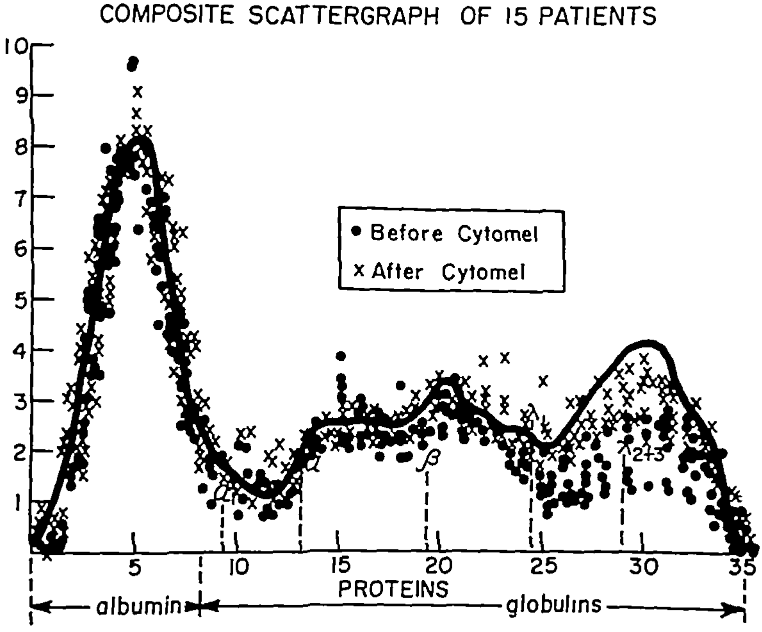

Fig 3

Fifteen patients with chronic pharyngitis and hypogammaglobulinemia followed the same pattern Thirteen of these were adults and two children, one a child of one of the adults The adults were maintained on ten micrograms of Cytomel for four days This raised their levels of Gammaglobulin almost to normal (see Fig 3) This increased level persisted for about three weeks and was coincident with the disappearance of their clinical symptoms During this period, the drawal It is absorbed readily from the gastro-intestinal tract, and rapidly cleared from the blood stream, being more loosely bound to the plasma proteins than thyroxin, hence, the oral administration would be the most satisfactory as well as the most effective

The first patient in whom the use of this drug was attempted was a five-year-old child with chronic Proteus middle ear infection Here, one antibiotic after another had been used until they had lost their capacity to destroy the infection After each subsequent cold, there was a return of the running ear, until no further medication was available Electrophoresis at this time confirmed a low serum Gammaglobulin level (see Fig 2) He was given five micrograms of Cytomel a day for four days without any effect, however, when the dosage was raised to ten micrograms of the sodium liothyronine a day for four days, the Gammaglobulin was raised to almost normal levels, and the ear improved tremendously This clinical effect lasted for about three weeks

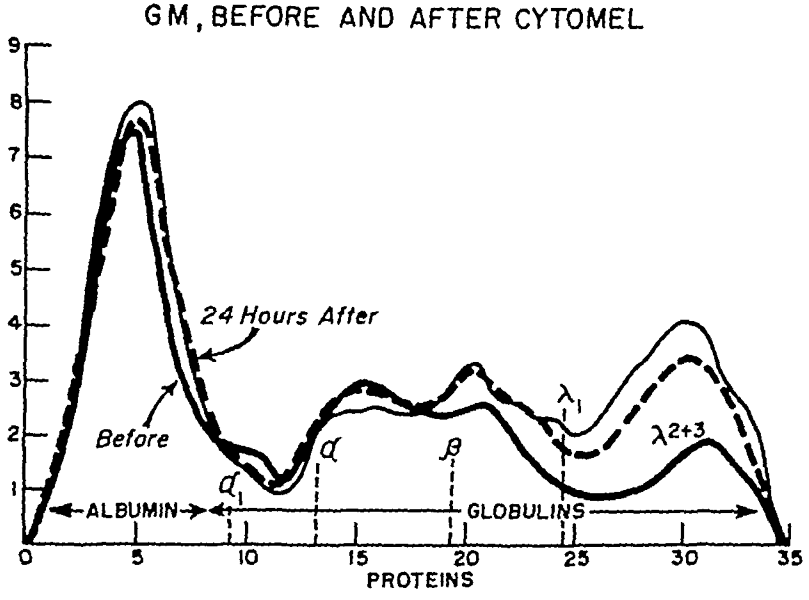

Fig 2

resistance with dysthyroidism but no effect with hypo- or hyperthyroidism

Protein bound iodine studies showed most of the levels within normal limits, usually close to the higher level of normal Very little rise was found with the small doses of Cytomel given

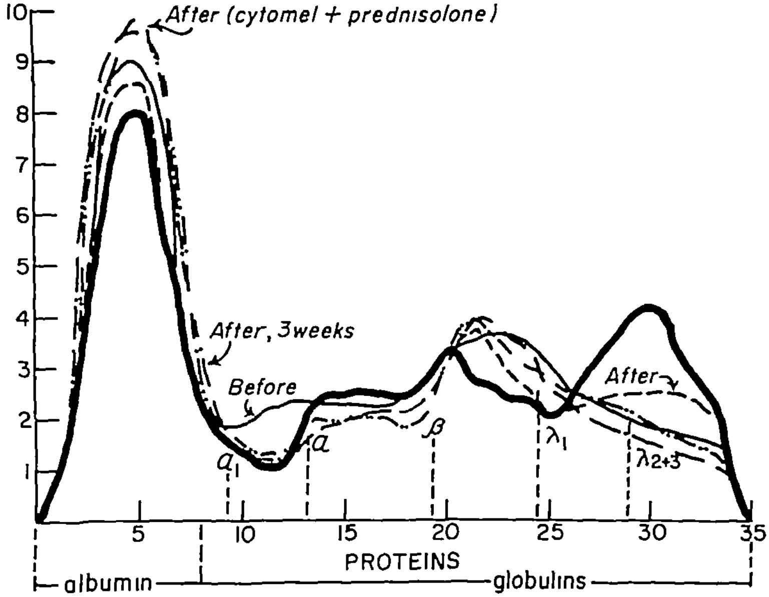

Fig 5

Since it is felt that the effect of liothyronine was mediated via the adrenal cortical hormones, an attempt was made to see whether this action could be enhanced by giving the patient 10 to 25 micrograms of Cytomel and five milligrams of prednisolone a day for four days To our dismay, the combination produced a lesser increase in the Gammaglobulin than did either drug alone, confirming the findings of Summers[9] and Hollender[10] that corticosteroids do not supplement thyroid therapy symptomatically It is felt that Cytomel may act through pituitary stimulation of the adrenals When adrenal hormone is also supplied, the stimulus is weakened and hence general lassitude, fatigue and throat soreness disappeared After several courses of the liothyronine the lymphoid nodules began to diminish in size as well as redness The electrophoretic patterns taken at the end of a three-week period usually demonstrated that the levels had diminished to the low present at the onset of treatment The children responded similarly to doses of five micrograms of Cytomel a day for four days It is interesting to note that of these two patients, a mother and son, had demonstrated very similar types of curve (see Fig 4)

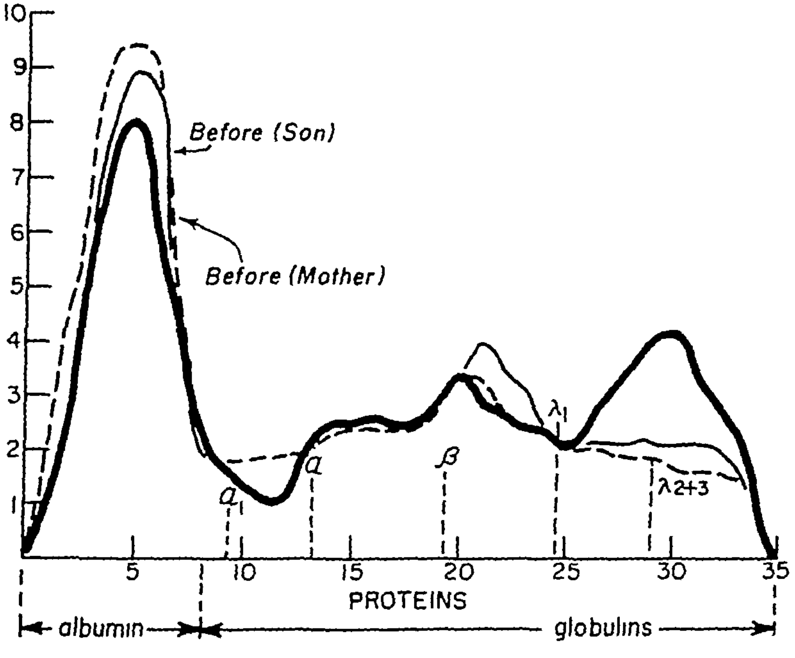

Fig 4

In three cases where 25 micrograms of Cytomel were given, the rise of the Gammaglobulin was less than with ten micrograms (see Fig 5) It is interesting to speculate why the response is limited to a narrow band, since the Gammaglobulin rise is lessened on either high or low doses This seems to agree with the clinical finding of a correlation of lessened

CAROTID BODY TUMORS

Report of One Case *†

FERNAND MONTREUIL, M D ,

Montreal, Canada

Carotid tumors are not frequent, and few surgeons have had the opportunity of operating on any large number of cases Small series of cases have been reported by several authors, many with an excellent review of the literature Morfit and co-authors, in a recent paper, emphasized two points which are brought out in the present case report First, these tumors are not as benign as previously claimed, and are found to invade locally and even disseminate, providing the cases are followed long enough Second, it is often possible to remove carotid body tumors without having to sacrifice the large vessels

This "potato tumor," as it is sometimes called, arises from the carotid body, a small ovoid mass found resting in the loose connective areolar tissue situated on the medial aspect of the carotid bifurcation Luschka was the first to describe this small organ, composed of an agglomeration of rounded lobules separated one from the other by fibrous septa containing blood vessels Each of these lobules is nourished by a small arteriole branching from a principal artery derived directly from the common carotid The cells are closely related to the vessels and are grouped into small nests or strands The shape of the cell is variable, a spherical nucleus has a fine chromatic network and the cytoplasm is granular, acidophilic and non-chromaffin Histologically similar non-chromaffin bodies or tissues are present along the aorta, the jugular bulb, the ganglion nodosum, the ciliary body (in the monkey), and finally in the coccygeal body The carotid is probably the best known of these bodies, forming what is now referred to

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*Read at the meeting of the Eastern Section American Laryngological Rhinological and Otological Society Philadelphia, Pa. Jan 1958

†From the Ear Nose and Throat Service Notre-Dame Hospital Montreal

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the response is poorer Another possibility is that Cytomel's action is a direct one on the protein fraction transporting the oxidation enzymes

In summation, further studies confirm our impression of a year ago that there are two types of hypogammaglobulinemia the *most* common type is the one reported by Good, in which there is little lymphoid tissue, the second is a numerically much smaller type in which hypertrophied lymphoid tissue is present, but where antibodies are not adequately secreted In this latter group, administration of liothyronine or cortical steroid hormones stimulates secretion of the lymphoid tissue The antibody liberated contains sufficient quantity of Gammaglobulin to show an effect on the electrophoretic pattern This has usually been accompanied by clinical improvement in our small number of cases This series is not large enough to do more than indicate the necessity of further study to help explain the inter-relationship *of hormones and resistance* to infection, however, for the clinician, it offers a valuable therapeutic tool in the aid of a small group of patients

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as the "chemoreceptor system" The physiology of this organ is not as yet well understood Its pathology appears to be limited to tumor formation only

The presence of a mass or lump in the neck may, for a long time be the one and only symptom of a carotid body tumor The mass has usually been present and slowly growing for a period of five to six years before the patient consults In a series of cases reported by Hendrick, the average duration of symptoms was eight years before patients sought relief The tumor is a slowly growing one It is deeply situated in the lateral portion of the neck, under the sterno-mastoid muscle, at the level of the carotid bifurcation The tumor is round or ovoid, firm to palpation and is not fixed to the skin It is neither painful nor tender It has been reported as being depressible and as transmitting pulsations It is movable in a lateral but not in a vertical direction, and does not move on swallowing As it increases in size the tumor may grow medially and project into the pharynx, or grow up and extend to the base of the skull Bulging of the pharyngeal wall was found to be a presenting symptom in a good number of cases, and in one reported by Hendrick, was such as to interfere with swallowing The tumor is usually unilateral, although bilateral cases have been reported Symptoms due to compression of surrounding structures are next in frequency Pressure on the recurrent laryngeal nerve, the vagus, the cervical sympathetic, the hypoglossal, the phrenic and the cervical plexus, causing corresponding paresis or paralysis, have all been reported In the present case the VIIth, VIIIth, IXth, Xth, and XIth cranial nerves were all involved It is unique in this respect, as no other case was found in the available literature in which so many nerves were affected

Grossly, a carotid tumor is a firm, reddish-brown, lobulated mass of variable size surrounded by a capsule

Histologically, Masson states that the tumor very closely reproduces the architecture of a normal carotid body The glandular lobules separated by fibrous septa containing vessels are increased, not only in number but also in size This explains the very marked vascularity of these tumors and the profuse hemorrhage with which their removal is always accompanied It would appear as a hyperplasia, and for this reason it has once been suggested that these tumors be called "goiters of the carotid body" (Dietrich and Siegmund) (see Figs 1, 2, 3)

The tumor is encapsulated, with the secondary nodules in turn, also encapsulated Long strands of cells are separated from one another by conjunctival septa, often presenting hyaline degeneration The cellular nests, or strands, are themselves divided into narrow trabeculae by a very fine conjunctivo-vascular system The cells are polygonal, with a fine granular cytoplasm and a comparatively small nucleus, which is hyper-chromatic One or two acidophilic nucleoli are often seen Two histological patterns are described, the alveolar and the peritheliomatous, in which the cellular units are smaller and more irregular than in the alveolar pattern

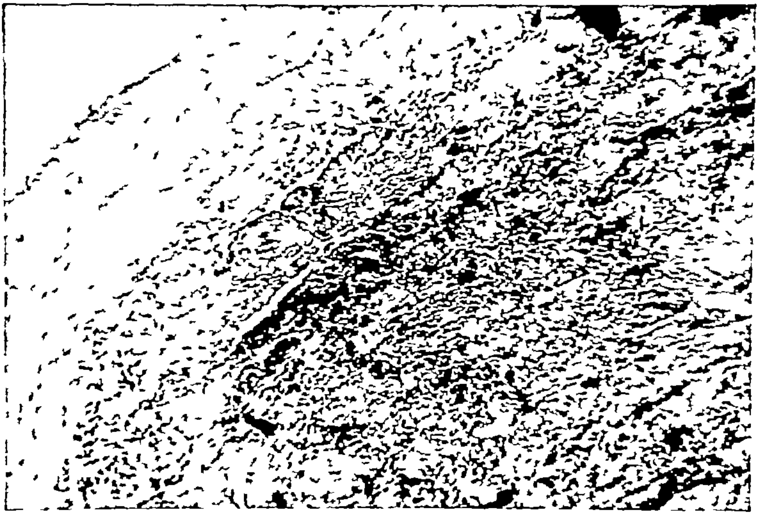

Fig 1 Microphotograph of carotid paraganglioma showing a well defined capsule X48

Masson considers most of these tumors benign but at the same time describes a malignant form, which he considers of low grade malignancy but capable of local and regional invasion Harrington and co-authors, in their review of 20 cases, reported evidence of malignancy in ten, as shown by active mitotic figures, cellular variations, giant cells and by invasion of the capsule Their criterion of malignancy is based on histological findings only, and not substantiated by follow-up or post-mortem examination On the other hand, Pettet and co-authors, after reviewing 314 cases found in the literature and 47 cases treated at Mayo, came to the conclusion that these tumors were very rarely malignant Goormaghtigh and Pattyn report two cases, one of which was malignant with metastases in the cervical, mediastinal and retro-peritoneal nodes, the lungs and lumbar vertebrae, proven at autopsy It can be concluded that there is no uniformity of opinion in regard to the malignancy of these tumors It is hoped that with time and a proper follow-up of operated and non-operated cases, a better understanding of carotid body tumors will result

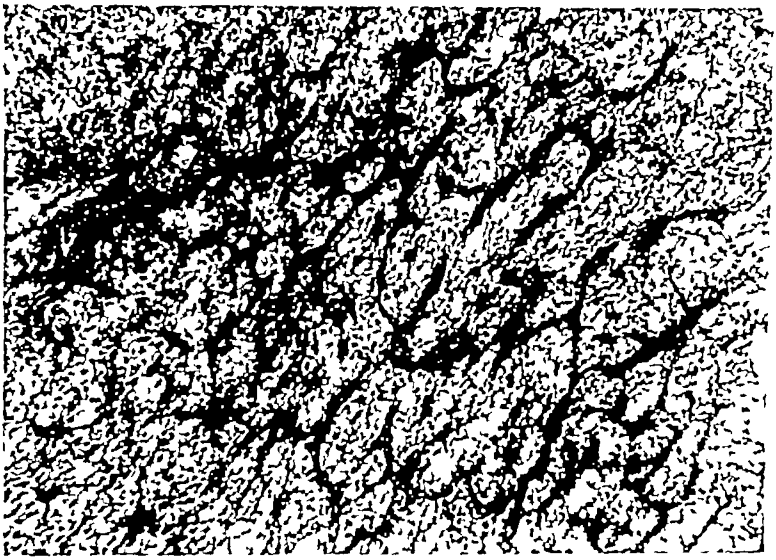

Fig 2 Cellular strand or nests are seen to be separated from one another by fibrous septa X60

The diagnosis of a carotid body tumor is not an easy one to make and few pre-operative diagnoses have been made The history of a slowly growing, non-tender mass in the lateral portion of the neck, at the level of the carotid bifurcation, movable in a lateral and not in a vertical direction, should make one suspect this type of tumor Aspiration biopsy has been recommended, but is not without danger, and is very often inconclusive

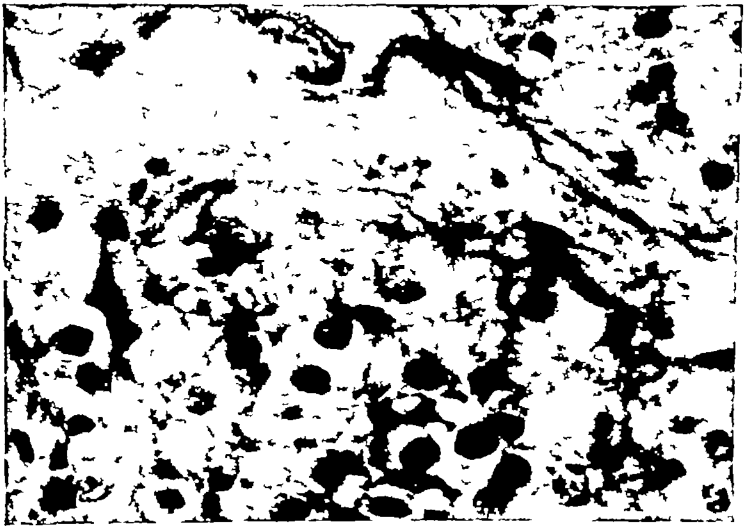

Fig 3 Higher magnification showing cellular details the Cytoplasm is granular acidophilic and non-chromaffin The nucleus is spherical and presents a fine chromatic network ×418

Carotid body tumors do not respond to radiation therapy and the treatment remains a surgical one Until recent years the indication and advisability of surgical removal was often questioned because of the high mortality and morbidity associated with the ablation of these tumors, particularly when excision of the carotid arteries became necessary It has now been shown that a great number of these tumors can be removed without injury to the vessels, if a careful dissection is done along the serosal plane of the arteries concerned, furthermore, when it becomes necessary to include the carotids along with the specimen, anastomosis or arterial grafts have been found quite successful in reducing this high mortality rate. This question is well discussed by Conley and others.

A 53-year-old male was referred by the Rehabilitation Center in April, 1954, for a laryngeal examination prior to vocal training, which had been recommended because of a hoarseness of some years standing. The history of this patient's complaints is long and complicated, but most interesting, and I shall briefly summarize it chronologically as follows:

In 1950 the patient first complained of hoarseness and saw a physician, who told him that he had an enlarged right tonsil, for which he recommended some ten treatments of deep radiotherapy. No change in either the hoarseness or the size of the right tonsil resulted.

In 1951 the tonsils were removed, and it was then realized that the right tonsil was not enlarged but was being pushed forward and medially by some extrinsic mass. Histological examination of the tonsil at this time did not reveal any pathology.

Shortly following tonsillectomy the patient noted a small swelling behind the angle of the jaw. According to the patient, this mass has varied from day to day until the present time.

Four or five months later the patient's voice became lower in pitch and less powerful. He also began having difficulty swallowing and reported that he would have frequent choking spells.

In 1952 weakness of the right shoulder and right arm were noted, and wasting of the sterno-mastoid and shoulder muscles quickly set in. At the time of consultation the patient stated that hearing in the right ear had been decreasing for the last six months or so.

X-rays of the chest in 1951 were reported as negative.

Examination (April 21, 1954)

The patient is a well developed and well nourished white male of about stated age He talks in a somewhat monotonous and muffled voice which definitely lacks volume Wasting of the sterno-mastoid and shoulder muscles on the right is quite apparent

Ears—Canals are normal Healed perforation in both drums

Nose—The septum is straight Mucous membrane is normal in appearance and no secretions are to be seen

Nasopharynx—There is a smooth bulging of the right lateral nasopharyngeal wall with loss of all landmarks The mucous membrane covering this mass is normal in appearance

Oropharynx—Dentures The tongue is normal in appearance and mobility The tonsils have been removed and the right tonsillar fossa is seen to bulge forward and medially This bulging or mass is continuous with that noted in the nasopharynx The soft palate on the right side and the uvula are deviated to the left There is no gag reflex

Larynx—The right cord is paralyzed in abduction, otherwise the larynx is normal There is considerable pooling of secretions in the right pyriform sinus

Neck—A marked atrophy of the sterno-mastoid and trapezius muscles on the right side is noted A firm mass can be palpated behind and below the angle of the jaw This mass, best palpated by bidigital palpation, is continuous with the mass noted in the oro and nasopharynx It is firm, non-tender and gives the impression of very slight mobilization in a lateral direction

A tentative diagnosis of tumor of the neck, probably mixed tumor, with paralysis by pressure of VIIIth, IXth, Xth, and XIth cranial nerves is made The patient is requested to come to hospital for further investigation and removal of this mass

The patient was admitted to N D H (4666) on May 2, 1954, and following examinations obtained

Audiometric—Total loss of hearing on the right.

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Examination (April 21, 1954)

The patient is a well developed and well nourished white was obvious that we were dealing, not with a mixed tumor but probably with a glomus tumor, because of its locality and its very marked vascularization The lower limit of the mass was at the level of the carotid bifurcation, and superiorly it extended to the base of the skull, where a round smooth erosion measuring about 1½ cm in diameter could be felt with the examining finger The tumor appeared to have originated

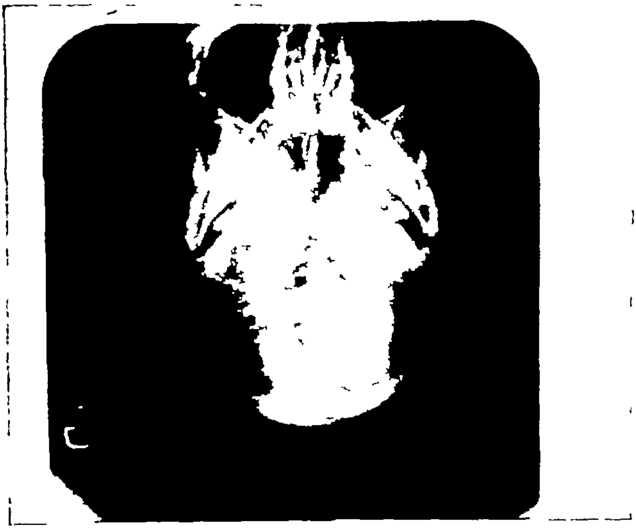

Fig 4 X-ray of the base of the skull shows a smooth erosion of the right petrous pyramid at the level of the jugular foramen. The internal auditory meatus has been completely destroyed

posteriorly to the internal carotid artery, around which it had extended and surrounded it laterally and partially covered its anterior walls It was very closely connected to the artery by numerous fibro-vascular bands, which took on pedicle-like proportions in its postero-inferior, inferior and antero-superior aspects

By a rather laborious blunt and sharp dissection, always attended by considerable oozing, the mass was finally liberated, except for its antero-superior attachments Prolonged efforts to free the mass at the base of the skull by finger dissection being unsuccessful, a tonsil snare was carefully

Vestibular—Complete loss of function of the right

Blood—RBC, 4,775,000, WBC, 8,250, Hmg, 97 Differential within normal limits

Urea and blood glucose normal

Bleeding and clotting times normal

Urinalysis normal

Neurological Consultation (Dr L Rinfret) Paralysis due to pressure by cervical tumor of VIIIth, IXth, Xth and XIth cranial nerves Some fibrillations of the right side of the face are noted, right facial weakness is suggested

Radiological Examination, May 12 Lungs are normal (C37339) Cranium and cervical region "Presence of a soft tissue mass bulging into the right side of the nasopharynx, which extends upwards through the base of the skull, into which it has produced a large defect posterior to the petrous pyramid at the level of the jugular foramen, furthermore, there is erosion of the posterior border of the pyramid with complete destruction of the internal auditory meatus This destruction does not involve the cochlea but has markedly thinned out the petrous bone This erosion extends posteriorly to the occipital foramen We are dealing with a large erosion with well defined contours It has the appearance of a destruction by pressure, most probably by a benign tumor The jugular bulb is most probably involved by the tumor We can definitely say that the VIIIth cranial nerve is involved, as are the nerves above or posterior to the VIIIth This is a nasopharyngeal lesion which has invaded the posterior fossa by destruction of the occipital bone and the petrous pyramid There are no signs of increased intra-cranial pressure or of pathological calcifications," Dr Léger (see Fig 4)

Surgery was performed under general penthothal anesthesia on May 11, 1954 Through a large horizontal incision the mass was exposed after mobilization of the flaps and the sterno-mastoid muscle, which was reflected backward Overlying the tumor a small lymph node was removed and found to be normal on frozen section After exposing the mass it tip and probably also involving the floor of the middle fossa, there was no evidence of pharyngeal or naso-pharyngeal mass Dr Rinfret, the neuro-surgeon, who had seen this patient prior to operation three years before, was called in on consultation Arteriography of the right carotid artery was unsuccessful, but the left carotid artery was injected with

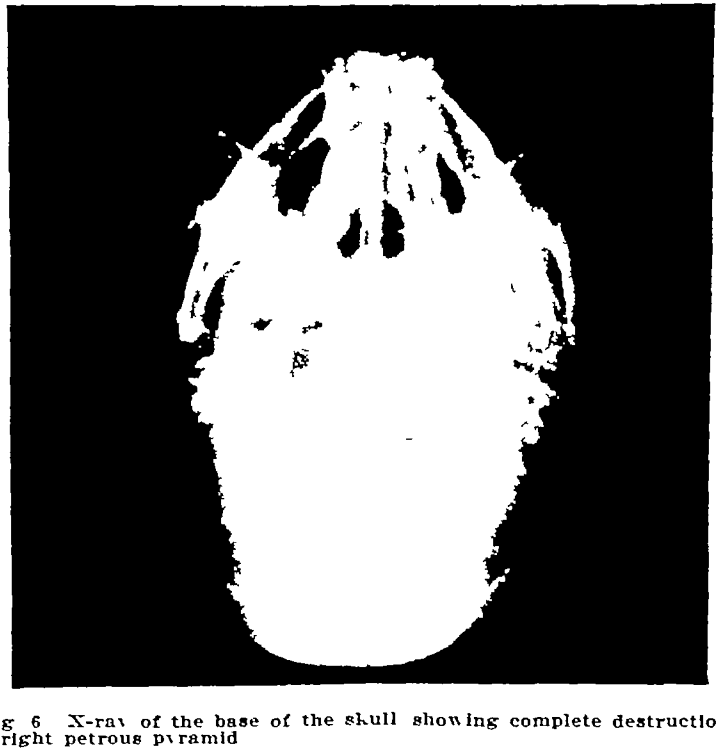

Fig 6 X-ray of the base of the skull showing complete destruction of the right petrous pyramid

Hypaque and showed nothing abnormal There was reflux of the dye into the right carotid and it was concluded that this one was probably occluded at the level of the petrous bone (see Figs 6, 7)

On October 18th, a ventriculography was unrevealing, and it was thought that the destructive process involving the petrous bone did not extend intra-cranially A right sub-inserted as high as possible and the tumor was snared off Examination of the specimen revealed an intact capsule During the operation, which the patient withstood without ill effects, 1000 cc of glucose and 1000 cc of blood were given The post-operative course was essentially uneventful and the patient was discharged from the hospital one week after surgery Pathology reported a softish, flattened 2 5x5x4 cm well encapsulated mass, which histological section revealed to be a carotid body tumor (see Fig 5)

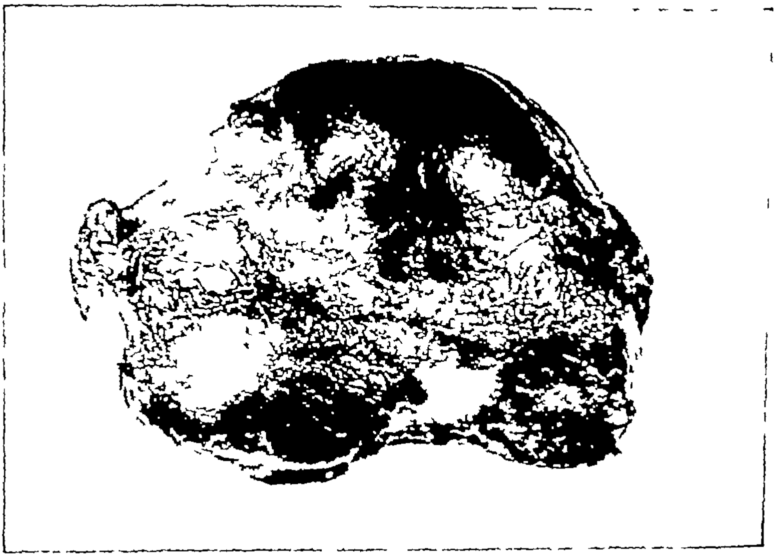

Fig 5 The surgical specimen measured 2 5x5x4 cm and was surrounded by an intact capsule

Three months after operation the patient reported some improvement in the movements of his arm, but all other paralyses remained the same There was nothing to note on periodic check-ups until October, 1957, at which time he reported that a right facial paralysis had gradually set in during a period of one month

The patient was admitted to the hospital for further investigation Externally, there was no evidence of recurrent tumor mass X-rays of the base of the skull showed complete destruction of the right petrous pyramid, extending to its

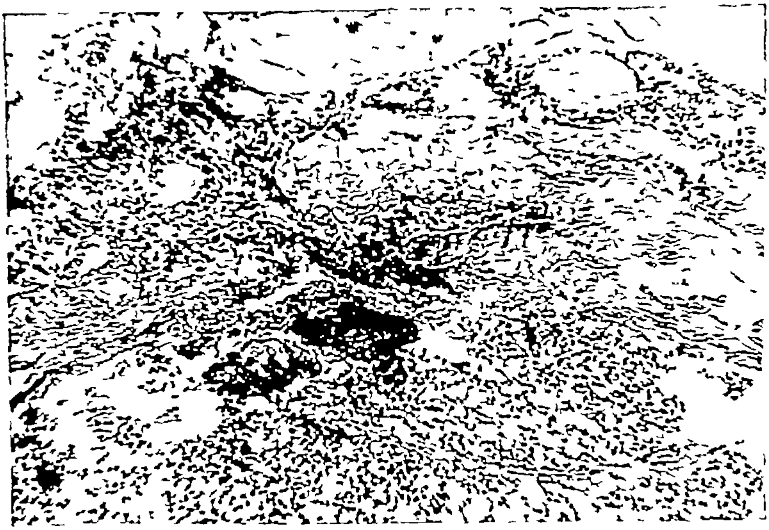

Fig 8 Microphotograph of the intra-cranial tumor shows paraganglionic cells invading the capsule X48

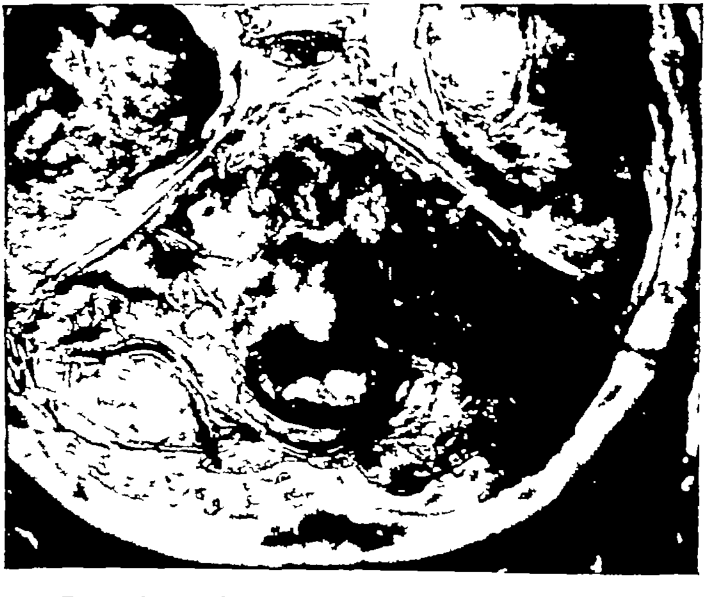

Fig 9 Base of the skull viewed intra-cranially The right petrous pyramid has been completely replaced by tumor

occipital craniotomy was then performed by Dr Rinfret After easy retraction of the right cerebellum a very hemorrhagic mass was exposed and as much of it as possible was removed This tumor proved to be carotid body tumor and showed the same histological pattern as the cervical tumor excised three years before except that in the present specimen

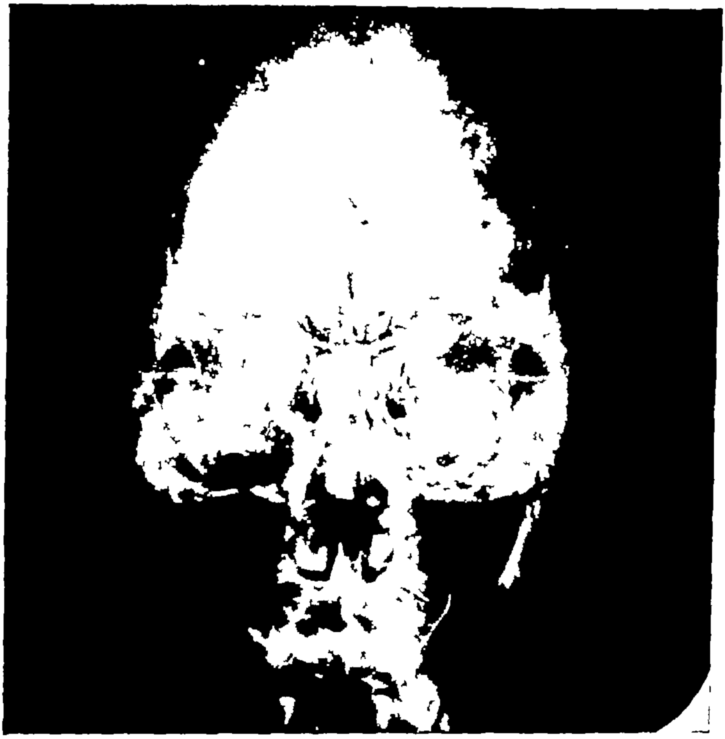

Fig 7 P A view showing destruction of the petrous bone

there was definite capsular invasion (see Fig 8) The patient never fully regained consciousness following surgery and died seven days later Post-mortem examination was most revealing The immediate cause of death was due to an infarct of the left posterior myocardium Examination of the base of the skull and the brain showed extensive invasion of the petrous bone and the right cerebellum The diameter of the petrous bone was enlarged throughout, and

The loss of function of the cranial nerves was slow and gradual, as shown by the complete loss of inner ear function without the patient having complained of subjective vestibular symptoms at any time The cranial nerves were at first probably involved through compression and not infiltration

Although somewhat tedious, the cervical mass was removed with an intact capsule without injury to the carotid arteries

Three years later extensive tumor formation was found to have destroyed all the petrous bone and invaded the right cerebellum with a minimum of symptoms

Both arteriography and ventriculography proved to be most misleading in this case

The tumor was locally malignant and invasive but did not metastasize Its growth was slow and destructive and probably extended over a period of more than seven years

It is difficult to believe that the intra-petrosal and intracranial tumors were an extension of the cervical tumor, as this one had been removed with a complete and intact capsule Multiple paragangliomas have been reported, and it is not unlikely that in the present case two independent tumors, one arising from the carotid body and one intra-cranial tumor taking origin from intra-petrosal non-chromaffin bodies developed

Photographs were taken by the Cancer Institute, Notre-Dame Hospital, Dr L C Simard, Director

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grossly appeared to have been completely replaced by tumor The petrous bone is being processed for serial sections It was impossible to free the right cerebellum because of its invasion by tumor measuring 5x2 5 cm The right cerebellar tonsil was deformed and the left one herniated The bulbar region was normal Dissection of the right carotid artery, which has been thought to be thrombosed, revealed it to be patent throughout (see Figs 9, 10)

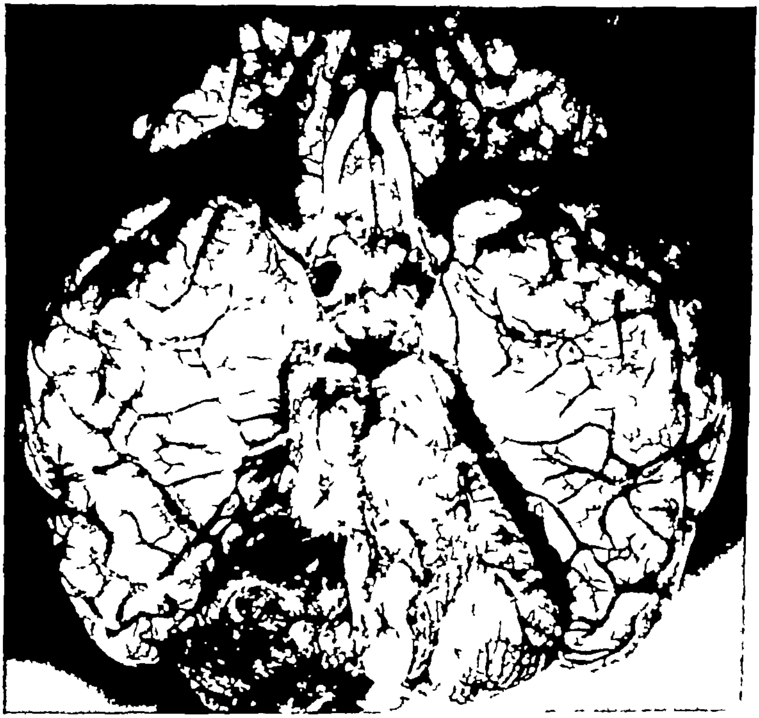

Fig 10 The brain viewed from below A large tumor mass has invaded the right cerebellum

Many points are of interest in this unusual case Four years had elapsed from the time the patient first complained of hoarseness to the time the cervical mass was removed

During this period four cranial nerves became involved as the tumor grew up and caused pressure and erosion at the base of the skull

OFFICE CLOSURE OF TYMPANIC PERFORATIONS A NEW APPROACH *

ARTHUR L JUERS, M D ,

Louisville, Ky

There has been considerable increase in interest concerning closure of central tympanic perforations in the past several years The advantages of closing a perforation are as follows

1 Improvement in hearing is usually obtained The degree of improvement to be anticipated can be estimated by comparing the initial audiometric test level with that obtained by placing a paper patch over the perforation In some instances the hearing level obtained by closure exceeds that obtained by patch application

2 The patient can tolerate getting water in the ear—permitting swimming, showers, etc

3 Recurrent otorrhea is unlikely to occur during respiratory infections

Closure treatment should be attempted in all dry central perforations in which a complete marginal rim exists The ear should be dry for several weeks before closure is attempted There should be no evidence of chronic middle ear or attic disease such as granulations, cholesteatoma debris or squamous epithelium invasion on the promontory The Eustachian tube should be inflatable

Older methods of perforation closure consisted of repeated marginal chemical cautery and the application of some type of patch In 1949 Dunlap and Schuknecht[1] reported their results in treating central perforations by means of repeated cautery and the daily instillation of a few drops of saturated solution of urea Of 20 perforations so treated, 11 had been closed with an average of 18 treatments each Six were still

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*Read at the meeting of the Southern Section American Rhinological Laryngological and Otological Society Memphis Tenn Jan. 26 1958

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1123 St Joseph Blvd East, Montreal

SOUTH CAROLINA SOCIETY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY

The next joint annual meeting of the North Carolina Eye, Ear, Nose, and Throat Society and the South Carolina Society of Ophthalmology and Otolaryngology will be held in Asheville, N C, on September 14-17, 1958, at Grove Park Inn An excellent program is in the making The following guest ophthalmologists will be present Dr James A C Wadsworth, New York, N Y, Dr Arthur Gerard DeVoe, New York, N Y, and Dr Frank B Costenbader, Washington, D C The following guest otolaryngologists will be present Dr F W Davidson, Danville, Pa, and Dr Tom Rambo, New York, N Y A third otolaryngologist will be announced in the near future A good attendance is anticipated

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was decided to rely largely upon marginal mechanical trauma to maintain an active border The inflammatory reaction is created by having the patient instill four drops of a urea boric acid solution in the ear canal twice daily Urea solution was first used for this purpose by Dunlap and Schuknecht[1] Linn[3] used Euthymol as an irritant solution

The addition of the use of loupe magnification in carrying out marginal treatment enabled me for the first time to appreciate what was taking place at the edge of the perforation Loupe magnification is absolutely essential Before any treatment is initiated, the margin of the perforation usually presents a beaded or rounded edge Whether the stratified squamous epithelium extends beyond the inner edge of the margin cannot be determined on external inspection Visible decrease in the size of the perforation does not occur until there is hyperemia of the tympanic membrane and a pink granular perforation margin The outer edge of the perforation then loses the "beaded" appearance somewhat

I first attempted to produce a traumatized perforation margin by serrating the edge with a myringotomy knife point Occasional activity was produced, but the results were not superior to the use of cautery After considerable trial and error a marginal eversion technique was evolved Special curettes and hooks are used for this purpose At the initial marginal treatment the curette edge is placed just within the perforation edge and brought out with fairly vigorous pressure against the margin The basic objective is to evert the marginal epithelium and leave the substantia propria exposed to start granulations Perforations which heal with rather vascular granulation formation seem to be less inclined to present an atrophic thin drum when healed than do those which have only minimal granulation formation In the healing process, the squamous epithelium sometimes seems to grow faster than the granulation tissue and again grows inward over the edge, thereby impeding further closure progress Granulations then accumulate behind the perforation margin on the tympanic side Everting the epithelium and "rolling" the granulation tissue outward into the plane of the perforation realigns the tissues so that closure again under treatment and three failed to show any evidence of healing In 1953 Derlacki[2] reported a modified version of a method of treatment originally described by Linn[3] He reported approximately 70 to 75 per cent closures The average number of treatments for those in which closure was accomplished was 14 6 Myringoplasty[4] techniques have been evolved in the past few years, because office closure treatment was rather prolonged and, even if continued a year or two, still left a sizeable number of failures

Dunlap and Schuknecht[1] describe the histopathology at the perforation margin as follows

> "The process of drum repair stops when the more hardy, rapidly growing stratified squamous epithelium of the external surface of the drum grows over the perforation edge and meets the pseudostratified columnar or cuboidal mucous membrane of the middle ear Destruction of the perforation margin with acid removes this epithelial barrier and, by tissue destruction incites an inflammatory healing response in the drum margin Fibroblastic proliferation in the middle layer of the granulating margin is responsible for the laying down of interlacing fibers of collagen The epithelium grows over the perforation in four days to a week, and must be repeatedly destroyed When collagen fibers are completely formed they shorten The shrinking of this circular band of interwoven collagen fibers may facilitate closure by purse string action"

Two clinical facts have been known for many years concerning the healing of tympanic perforations The first is that many fresh traumatic perforations will frequently heal rather promptly Second, healing is sometimes accelerated if there is some secondary tympanic infection It, therefore, seemed logical that closure treatment should incorporate these two basic principles, *i e*, maintaining a raw, traumatized perforation margin and, by means other than infection, producing the equivalent of an inflammatory reaction The objection to using repeated chemical cautery, once the healing process is initiated, is that the proliferative margin is partially destroyed each time cautery is applied For this reason it was decided to rely largely upon marginal mechanical trauma to maintain an active border The inflammatory reaction is created by having the patient instill four drops of a urea boric acid solution in the ear canal twice daily Urea solution was first used for this purpose by Dunlap and Schuknecht[1] Linn[3] used Euthymol as an irritant solution

The addition of the use of loupe magnification in carrying out marginal treatment enabled me for the first time to appreciate what was taking place at the edge of the perforation Loupe magnification is absolutely essential Before any treatment is initiated, the margin of the perforation usually presents a beaded or rounded edge Whether the stratified squamous epithelium extends beyond the inner edge of the margin cannot be determined on external inspection Visible decrease in the size of the perforation does not occur until there is hyperemia of the tympanic membrane and a pink granular perforation margin The outer edge of the perforation then loses the "beaded" appearance somewhat

I first attempted to produce a traumatized perforation margin by serrating the edge with a myringotomy knife point Occasional activity was produced, but the results were not superior to the use of cautery After considerable trial and error, a marginal eversion technique was evolved Special curettes and hooks are used for this purpose At the initial marginal treatment the curette edge is placed just within the perforation edge and brought out with fairly vigorous pressure against the margin The basic objective is to evert the marginal epithelium and leave the substantia propria exposed to start granulations Perforations which heal with rather vascular granulation formation seem to be less inclined to present an atrophic thin drum when healed than do those which have only minimal granulation formation In the healing process, the squamous epithelium sometimes seems to grow faster than the granulation tissue and again grows inward over the edge, thereby impeding further closure progress Granulations then accumulate behind the perforation margin on the tympanic side Everting the epithelium and "rolling" the granulation tissue outward into the plane of the perforation realigns the tissues so that closure again under treatment and three failed to show any evidence of healing. In 1953 Derlacki[2] reported a modified version of a method of treatment originally described by Linn.[3] He reported approximately 70 to 75 per cent closures. The average number of treatments for those in which closure was accomplished was 14.6. Myringoplasty[4] techniques have been evolved in the past few years, because office closure treatment was rather prolonged and, even if continued a year or two, still left a sizeable number of failures.

Dunlap and Schuknecht[1] describe the histopathology at the perforation margin as follows:

"The process of drum repair stops when the more hardy, rapidly growing stratified squamous epithelium of the external surface of the drum grows over the perforation edge and meets the pseudostratified columnar or cuboidal mucous membrane of the middle ear. Destruction of the perforation margin with acid removes this epithelial barrier and, by tissue destruction incites an inflammatory healing response in the drum margin. Fibroblastic proliferation in the middle layer of the granulating margin is responsible for the laying down of interlacing fibers of collagen. The epithelium grows over the perforation in four days to a week, and must be repeatedly destroyed. When collagen fibers are completely formed they shorten. The shrinking of this circular band of interwoven collagen fibers may facilitate closure by purse string action."

Two clinical facts have been known for many years concerning the healing of tympanic perforations. The first is that many fresh traumatic perforations will frequently heal rather promptly. Second, healing is sometimes accelerated if there is some secondary tympanic infection. It, therefore, seemed logical that closure treatment should incorporate these two basic principles, *i.e.*, maintaining a raw, traumatized perforation margin and, by means other than infection, producing the equivalent of an inflammatory reaction. The objection to using repeated chemical cautery, once the healing process is initiated, is that the proliferative margin is partially destroyed each time cautery is applied. For this reason it cover the perforation margin and the adjacent outer surface of the tympanic membrane In one instance some of the anesthetic reached the middle ear, and a short period of vertigo followed Complete anesthesia is difficult to obtain near the malleus and near the tympanic ring

2 *Treatment of Perforation Margin.*

On the initial marginal treatment, I have used chemical cautery on only a few In the majority, the marginal eversion technique was used In one instance (Ear No 2) a combination of cautery and marginal curettage was used The combination may be better as an initial treatment than either method by itself Further clinical experience will be necessary on this point

On all follow-up treatments the marginal eversion method was used exclusively as soon as the margin became "active" If the margin has a fine granular appearance and the somewhat gray epithelial layer is not growing inward, only gentle eversion and "freshening" of the granular tissue is carried out with the curette No attempt is made to cut out granulation tissue If the epithelium is growing inward over the edge, the margin again has a more firm, "rolled in" appearance, and the epithelial layer is then everted with the curette and hook Granulation tissue on the inner surface is everted Some bleeding ensues, but this is not removed, as a blood clot may serve as somewhat of a matrix for connective tissue growth across the perforation

When the perforation extends to the edge of the malleus, the edge of the pars tensa seems to wrap partially around the malleus handle and is separated from the malleus by means of the curette and hook This frees the edge of the tympanic membrane and facilitates the start of granulation tissue formation In ear No 8 a large granular mass formed around the end of the malleus after a few treatments, and the progress of healing was very rapid thereafter

3 *Placement of Cottonoid® Patch*

In the Linn treatment, a small piece of cotton was fashioned into a pad and placed against the tympanic membrane It progresses In general, the granulations should be everted rather than cut away There may be occasional exceptions on which comment will be made under the discussion of cases

MARGINAL EVERSION TECHNIQUE

1 *Anesthesia*

Adequate anesthesia of the perforation margin is essential, as the marginal manipulations are too painful to be tolerated without anesthesia Block injection anesthesia such as is used for stapes mobilization was not entirely effective and, furthermore, is not practical as a repeated office procedure After trying various preparations I found Bonain's solution the most effective, but was somewhat hesitant to use this preparation because of its slightly caustic nature, apparently it is well tolerated Perhaps a minimal degree of chemical irritation accelerates the desired inflammatory action Just enough is applied with a small cotton-tipped applicator to

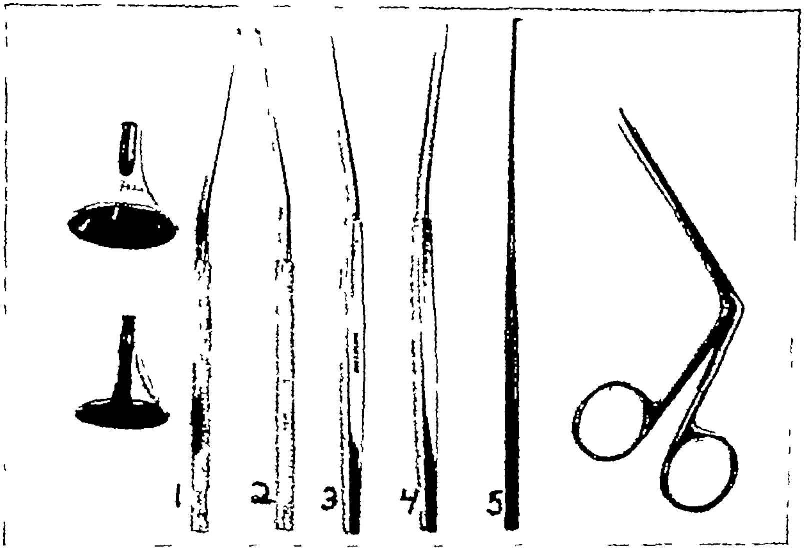

Fig 1 A wide aperture Boucheron ear speculum is preferred Instruments Nos 1 and 2 are special 00 curettes with special angles to permit an unobstructed view while working The ring is sharp on both sides (Storz) Nos 3 and 4 are sharp right angle hooks (V Mueller) No 5 is a Day ear hook A small standard alligator forceps is used to place the cottonoid patch in the ear canal

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3 Placement of Cottonoid® Patch

In the Linn treatment, a small piece of cotton was fashioned into a pad and placed against the tympanic membrane It seemed that the rounded contour of the pad would tend to invert the epithelial edge and impede progress of the granulation activity Consequently I have used a flat compressed cotton preparation known as Cottonoid® The commercial preparation is rather thick and is split in half A piece is cut out to approximate the size of the tympanic membrane It is moistened with the urea-boric acid drops in order to make the patch more flexible, and is then placed against the drum with an alligator forceps With a small blunt Day ear hook it is pressed against the entire membrane, care being taken not to push it through the perforation

4 Irritant Drops

This solution consists of 2 per cent boric acid and 5 per cent urea in physiological saline The patient is instructed to instill 4 or 5 drops twice daily Definite hyperemia is induced Occasionally the patient will complain of a slight feeling of irritation at first The urea is the irritant factor, and the boric acid was added to lessen any tendency toward annoying infection

Mucoid discharge from the middle ear developed in a few instances This was removed from the middle ear by inflation and aspiration Treatment of the perforation was continued in these cases, and the added middle ear reaction may have accelerated the rapidity of closure Should a definite suppurative process develop, then closure treatment should perhaps be temporarily interrupted and the otitis appropriately treated

5 Interval of Treatment

Marginal treatment has, in general, been carried out at two-week intervals Whether this is the optimal interval remains to be determined The number of cases treated has been too small to vary the technique appreciably It is possible that inactive margins should be treated more often The tissues must, of course, be given time to react

DISCUSSION OF CASES

The treatment of 15 consecutive central perforations is summarized in Table I Each circle represents the tympanic membrane, showing the size and location of the perforation at each treatment Several significant observations have been noted

In studying the change in shape of the larger perforations it is evident that the initial closure progress is generally in the central portion of the tympanic membrane A bean shaped perforation assumes an oval appearance The portion of the perforation margin closest to the malleus shows earlier hyperemia and marginal granulation than does the area adjacent to the tympanic ring This is undoubtedly due to the fact that the malleolar vessels become hyperemic more readily than do those in the lower portion of the membrane Healing does not progress until hyperemia is evident

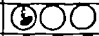
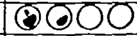
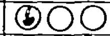
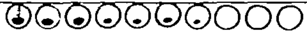
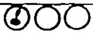
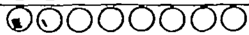
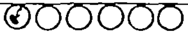
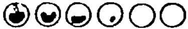
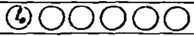
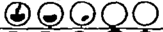
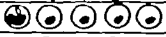
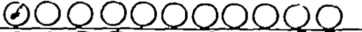
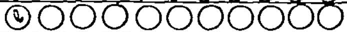
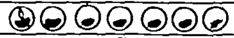
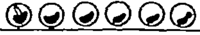
NAME AGE		EAR NO	HEARING BEFORE CLOSURE	 AFTER CLOSURE	
T W 13	R.	1	8	2	
	L	2	25	5	
J A 27		3	45	30	
H.S. 33		4	38	15	
N.K. 36		5	30	8	
C.R. 47		6	33	8	
T.J 56		7	33	15	
M.S 43		8	20	3	
L.R 29		9	10	3	
J W 8	R.	10	22	3	
	L	11	30		
J.W 24	R	12	7		
	L	13	7		
E.H. 29		14	17		
O.H 54		15	62		

TABLE I

Ears Nos 11, 14 and 15 showed early healing activity in the perforation margin nearest to the malleus, however, the inferior portion nearest the tympanic rim continued to show a firm, beaded non-granular margin At the sixth treatment in each, the inferior margin of the perforation was cauterized with trichloracetic acid and vigorously curetted Ears Nos 14 and 15 are beginning to show granulation activity in the entire marginal circumference following the cautery and curette treatment Ear No 11 is still rather inactive, due to the fact that the patient frequently omits the instillation of the drops On a few occasions the patch appeared quite dry when the patient came in for treatment

The tympanic membrane in ears Nos 12 and 13 (patient J W) showed a thick pale appearance rather than one of hyperemia Even though the perforations were small, healing progress has been virtually nil The epithelium has persistently inverted during the interval between treatments Though abundant granulation tissue has formed, it has been pale in appearance rather than the usual pink The tissues present almost an allergy-like reaction rather than an inflammatory one At the tenth treatment all granulation tissue was removed with a curette and the margin cauterized At the time of this writing, it is too soon to state whether healing progress will ensue It may be necessary to change the nature of the drops in this case Ultimate healing should be possible since the perforations are small

In summarizing the results obtained by this method of treatment, it is noted that 10 of 15 perforations so treated have to date closed with an average of 4 2 treatments each Three of the remaining five cases have shown some initial progress (ears 11, 14 and 15) and then reached a standstill I believe that the reason for this lack of continued progress is due to insufficient mechanical trauma to initiate healing in the inferior margin of the perforation In the future management of such cases it is planned to use marginal cautery and curettage to the inactive portion of the perforation margin on the second or third treatment if granulation formation is not apparent at this time An additional reason for slow progress in ear 11 is that this patient did not use the drops regularly The need for regular use of the drops must be explained and stressed at the beginning of treatment The exact reason for progress failure in ears Nos 13 and 14 remains to be determined Since these perforations are relatively small, it is possible that some variation from the above routine may meet with eventual success

A few patients with central perforations were not able to come in for regular treatment and were treated with only marginal eversion and the application of a dry paper patch without the use of drops One healed promptly, and the other is showing satisfactory progress My impression is that healing in these were more rapid than was noted in the past when cautery and a dry patch were used These cases are not included in the tabulation

SUMMARY

1 A new approach to office closure of central tympanic perforations is presented It embodies the following changes from previously reported methods

a The use of loupe magnification to reveal details of marginal changes during the progress of healing and to permit more precise mechanical technique of marginal traumatizing measures

b The use of marginal trauma, rather than cautery, after healing progress has been initiated

c Everting the marginal granulation tissue and epithelium

d Using a flat "Cottonoid®" patch in order to lessen the liklihood of inverting the marginal epithelium

e The use of Bonain's anesthesia before treatment

2 Ten central perforations have been healed with an average of 4 2 treatments each The other five cases are still under treatment, and three of these are showing progress

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PRIMARY CLOSURE OF THE RADICAL MASTOIDECTOMY WOUND, A TECHNIQUE TO ELIMINATE POSTOPERATIVE CARE *

J H THOMAS RAMBO, M D ,†

New York, N Y

It has been said that the history of medicine furnishes no chapter which excels in interest the one devoted to perfecting surgical procedures for the alleviation of suppurations within the temporal bone To the pioneers in the surgery of chronic otorrhea we owe the fact that the radical mastoidectomy, as practiced today, has reduced the mortality in chronic temporal bone surgery to a minimum, however, the problem of getting a dry, healed ear following this surgery has not been solved by the progress in surgical techniques for the removal of pathological processes That the problem continues to exist needs no elaboration, for it is common to all who do mastoid surgery

In a previous paper, entitled "Factors Affecting Healing Following Temporal Bone Surgery,"[1] I pointed out that the temporal bone surgeon, unlike the general surgeon dealing with soft tissue wounds, does not have the crucial advantage of being able to close his surgical wounds primarily Our two greatest handicaps are *1* That our wounds must heal by secondary repair, *2* that the healing processes are supported by a poor blood supply derived from a bony cavity These difficulties result not only in a poor quality of healing, but also in a slow process of healing which often allows complicating factors to develop that further delay or completely arrest the progress of repair I also pointed out that in this course of events the advantage of good temporal bone surgery is often lost because the ear continues to drain

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†From the Department of Otolaryngology New York Eye and Ear Infirmary

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Although I had long considered the problem, when the article referred to above was written I did not see the possibility of developing a surgical technique for primary closure of a radical mastoid wound which would eliminate the need for postoperative care The problem consists of closing an endaural opening with tissue that overlies an air cavity Free skin grafts placed in the breech would slough due to the lack of blood supply, and the extent of skin available from the external auditory canal, in any combination of pedicle flaps, is inadequate to close an enlarged endaural opening

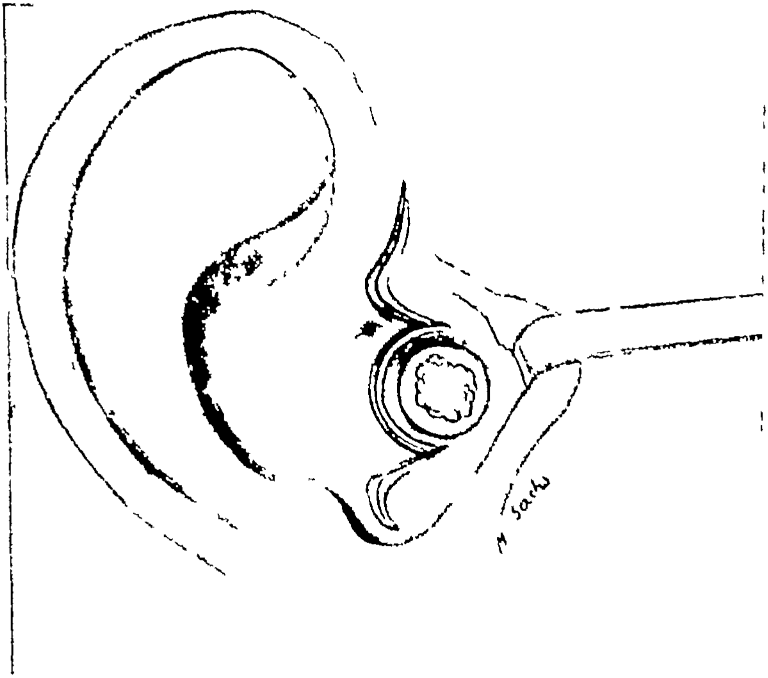

Fig 1 The endaural incisions consist of superior and inferior incisions from the drum outward joined posteriorly by a circumferential incision just superficial to the drum

During the past year-and-a-half my experience with the temporal muscle plastic, in the performance of musculoplasty, has suggested a method for primary closure of the radical mastoidectomy wound As used in musculoplasty,[2,3] the temporal muscle plastic has solved the vital problem inherent in all reconstructive surgery of the middle ear, that of bridging an air-containing middle ear space It has accomplished this by reason of the fact that a pedicle flap not only makes available any necessary amount of tissue to cover a large air space, but also carries with it a self-sustaining blood supply, it does not need to obtain blood supply from adjacent structures The same principle can be used to close an endaural opening

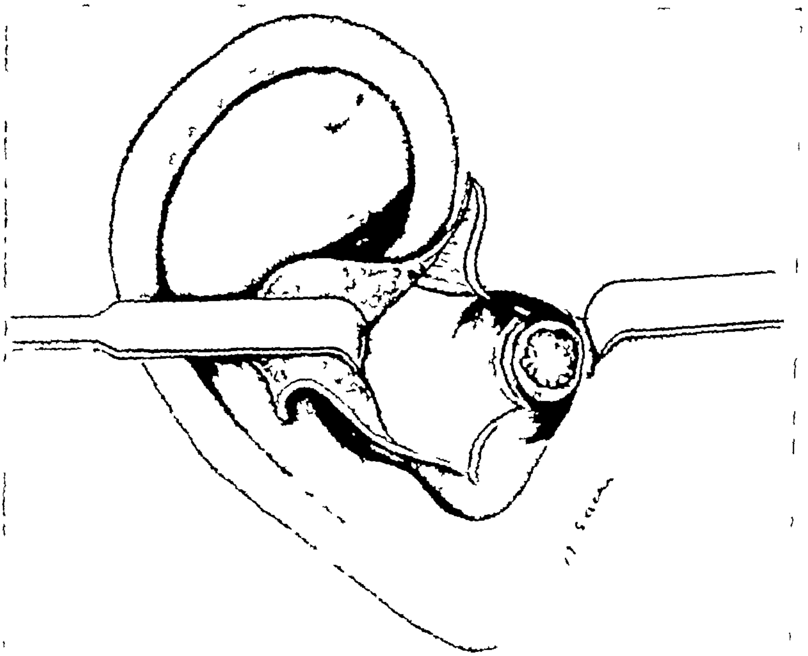

Fig 2 The skin of the posterior half of the external auditory canal is reflected as a pedicle flap An elliptical piece of conchal cartilage is removed and the mastoid cortex exposed

The technique is described in the legends accompanying Figs 1 through 9, which follow

COMMENT

Now what is actually being done with this technique? It is simply a way to cooperate with nature's efforts to close off a wound in the temporal bone in the most direct and efficient way possible. It is a natural physiological condition to have a permanently closed air space within the temporal bone open to the pharynx through the Eustachian tube It is present in the normal ear, consisting of the middle ear cavity and the antrum (see Fig 10-A)

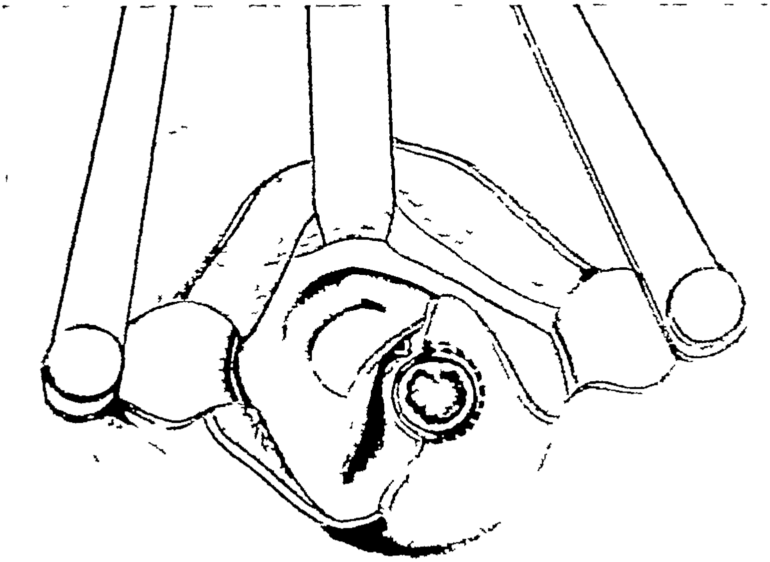

Fig 3 The mastoid is excavated to remove all diseased tissue The bony posterior canal wall is taken down a circumferential incision is then made anteriorly to separate the canal skin from the drum

After a simple mastoidectomy, with removal of the bone in the mastoid region, a larger space results, consisting of the middle ear, the antrum, and the mastoid cavity (see Fig 10-B) For many years we have been closing off this enlarged air cavity by primary wound closure with after care that is practically negligible This has made the simple mastoidectomy the most gratifying operation available today in temporal bone surgery, for both the patient and the surgeon

With primary closure of the radical mastoidectomy wound we are following the same principle We simply enlarge the cavity to include not only the mastoid area but also the space previously occupied by the external auditory canal (see Fig 10-C) It does not matter whether the space is large or small so long as it is connected to the pharynx through the Eustachian tube In each of these instances of enlarging the normal air cavity in the temporal bone, the space is maintained by air pressures through the Eustachian tube, while mucosa extends itself into the enlarged cavity Only one thing is essential, a thorough radical mastoidectomy must be performed In addition to the removal of all foci of infection, particular attention must be directed to the elimination of any type of

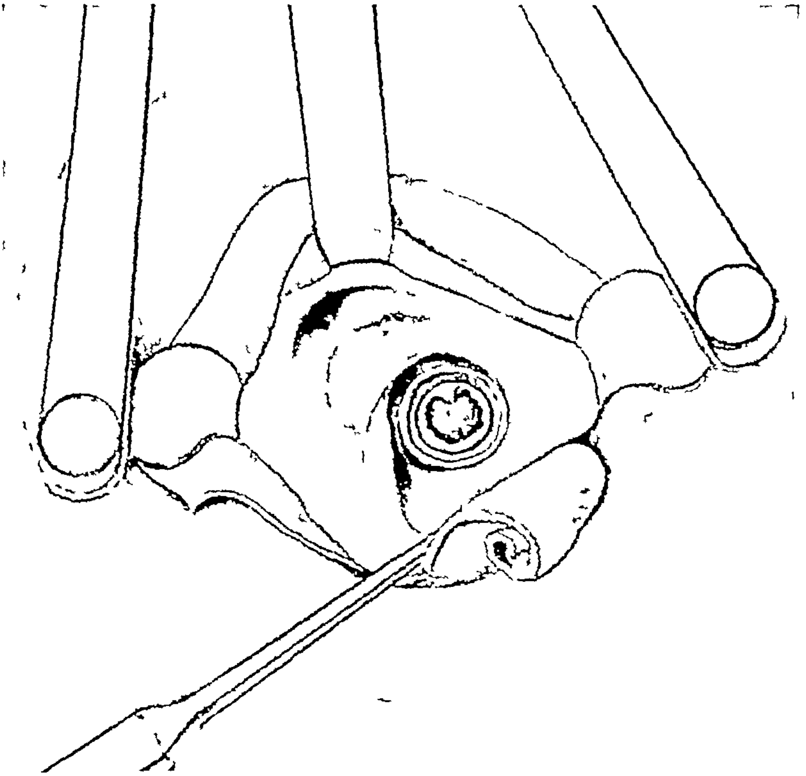

Fig 4 The anterior canal skin is then reflected as a pedicle flap

squamous epithelium It is perfectly clear that remnants of cholesteatomatous material cannot be left in a cavity that is to be permanently closed

This method furnishes a durable healing which will not break down, as it often does in secondary repair when poorly nourished epithelium has grown over bone With primary closure of the radical mastoidectomy wound, patients may take showers and swim Another important advantage is that there is no postoperative cavity which requires periodic care

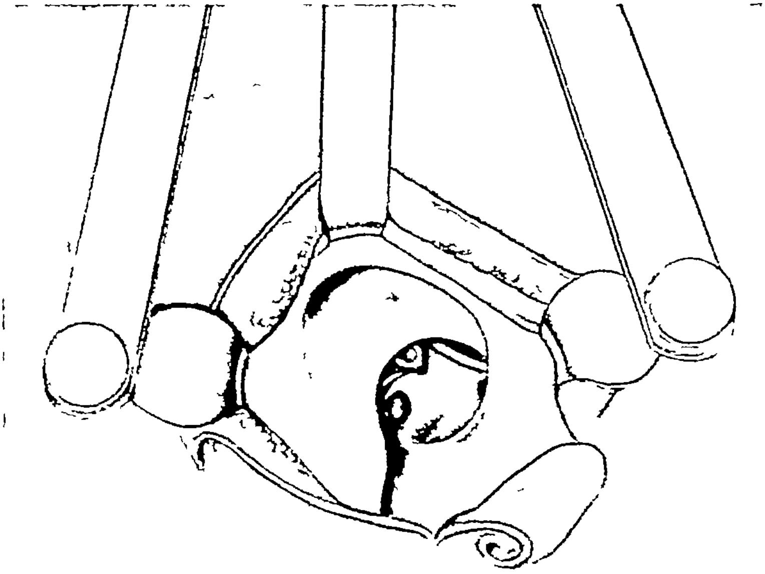

Fig 5 With the skin of the external auditory canal reflected out of the way as two pedicle flaps the radical mastoidectomy can then be completed with meticulous removal of all epithelial and diseased processes

Today, restoration of hearing in deafness, caused by long-standing chronic otitis, is being accomplished In such cases

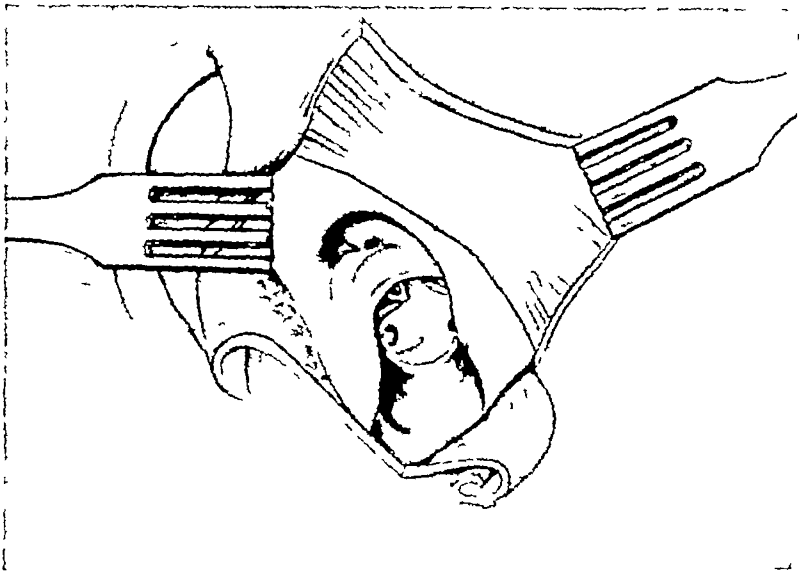

Fig 6 The temporal muscle is then exposed by extending the superior endaural incision upward and by separating the loosely attached scalp from the temporal fascia

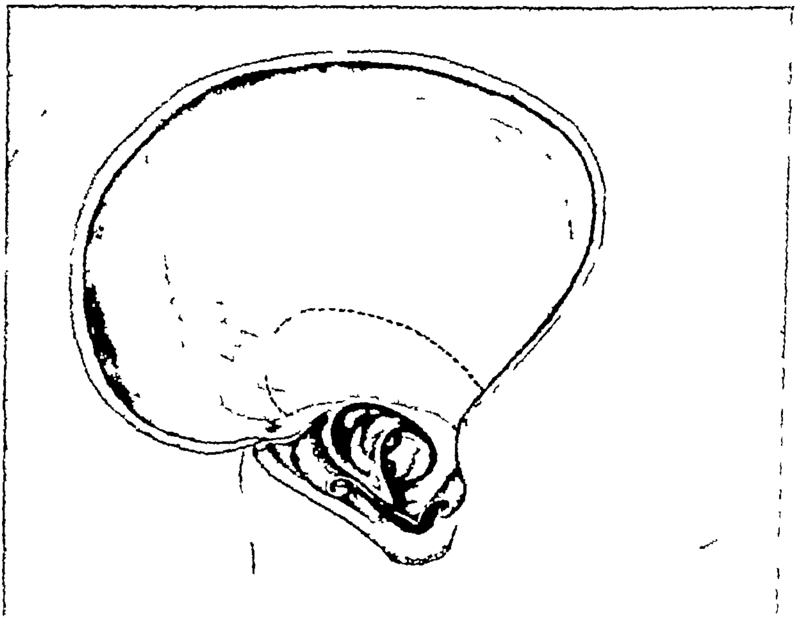

Fig 7 A temporal muscle pedicle flap is cut as indicated The flap receives an abundant blood supply mainly from the posterior deep temporal artery which courses upward and backward in the area of the muscle included in the flap

an open cavity is essential for the transmission of sound vibrations to the inner ear Primary closure is not suggested, of course, in these ears, where an open cavity serves a useful purpose, but it is a logical procedure for those patients with poor bone conduction, where an open cavity does not serve any useful purpose Aside from those in whom bone conduction is a consideration, there is also a large group of patients with chronic ears who either do not wish to have an extensive plastic reconstructive operation, or for whom such an operation would not be indicated in the best judgment of the surgeon Among these are the very young, the very old, and those with serious systemic disease Patients with one normal ear who have no real hearing handicap but who would like to get rid of the basic disease and symptoms, and

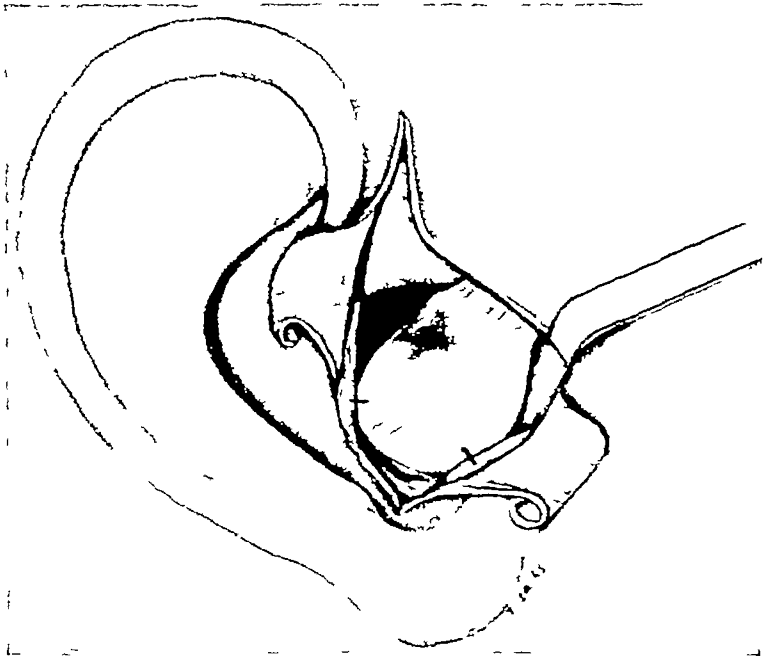

Fig 8 The temporal muscle pedicle flap is then rotated over the area of the endaural opening The free end is sutured anteriorly and posteriorly to the soft tissue underlying the skin

get a dry ear in the simplest and easiest way possible, might well be considered logical choices for the procedure

Even where an open cavity is maintained, the use of the temporal muscle plastic in a postoperative radical cavity—to create a closed middle ear space and to line the cavity with soft tissue which contributes an abundant blood supply—has proved an excellent way of getting prompt healing The problem of secondary healing is mainly one of blood supply For instance, we need only to recall how well scalp wounds heal, where there is a rich blood supply In those radical mastoidectomies, where this technique has so far been used to promote healing, and in one-stage musculoplasties as well as in the first stage of two-stage musculoplasties, the abun-

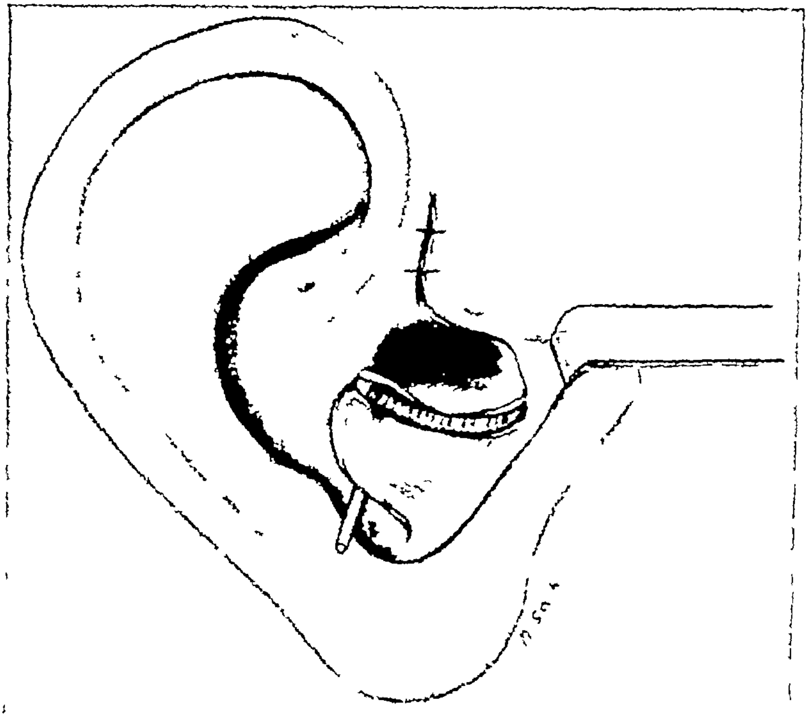

Fig 9 The two pedicle skin flaps previously prepared are then laid in place over the muscle The superior endaural incision is sutured a polyethylene tube is left in place for several days as a temporary drain from the cavity

dant blood supply furnished by the temporal muscle pedicle flap has given a rapidity of healing that has been almost a revelation It must be pointed out, however, that although this method has provided rapid and uncomplicated healing following the classical radical mastoidectomy, it does not provide all the advantages of primary closure These are quick healing by primary intention, the elimination of a cavity which requires periodic postoperative care, and the elimination of restrictions on the part of the patient concerning swimming and taking showers

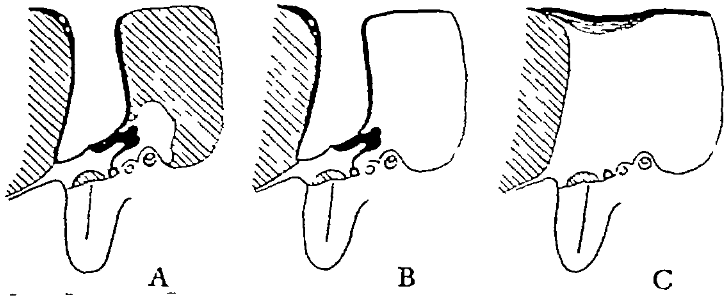

Fig 10-A. Air space in the normal ear B—Air space following simple mastoidectomy C—Air space following radical mastoidectomy with primary closure

Whether techniques are directed toward restoration of hearing, or simply to a cure of the basic disease and attempts to obtain a dry ear, my experience thus far leads me to the conviction that the use of the temporal muscle plastic in surgery of the chronic ear will prove to be the solution to the problem of the persistently draining postoperative cavity

BRIEF REVIEW OF TYPICAL CASES

Case 1 A 60-year-old woman with fair bone conduction In the ear operated she had a large perforation of the drum destruction of the ossicular chain suppuration and a large polyp protruding into the external auditory canal She complained of headaches and some instability of balance No practical hearing had been present in the ear for ten years and she had become well adjusted to getting along with the adequate hearing in the other ear The patient worked in a department store and she volunteered the information that postoperative visits would be difficult for her to arrange She was interested only in getting rid of her symptoms and the chronic otorrhea with the least possible get a dry ear in the simplest and easiest way possible, might well be considered logical choices for the procedure

Even where an open cavity is maintained, the use of the temporal muscle plastic in a postoperative radical cavity—to create a closed middle ear space and to line the cavity with soft tissue which contributes an abundant blood supply—has

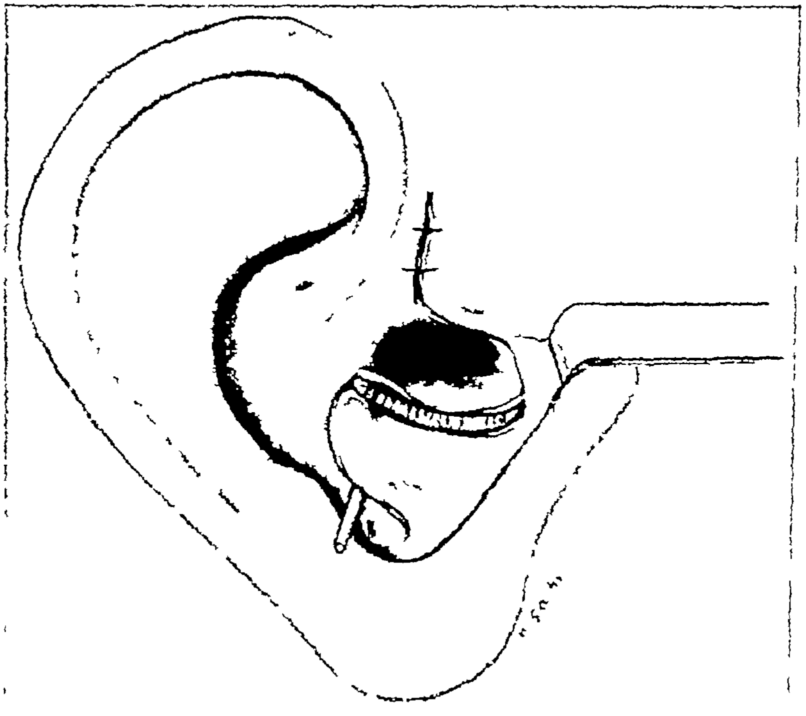

Fig 9 The two pedicle skin flaps previously prepared are then laid in place over the muscle The superior endaural incision is sutured a polyethylene tube is left in place for several days as a temporary drain from the cavity

proved an excellent way of getting prompt healing The problem of secondary healing is mainly one of blood supply For instance, we need only to recall how well scalp wounds heal, where there is a rich blood supply In those radical mastoidectomies, where this technique has so far been used to promote healing, and in one-stage musculoplasties as well as in the first stage of two-stage musculoplasties, the abunwas revised and a technique for obtaining rapid healing which differs from the three preceding cases was utilized This consisted of bringing a long pedicle flap, cut from the temporal muscle down into an open cavity to contribute an abundant blood supply to the healing processes and to bridge and seal the middle ear space Three weeks after operation the patient was forced to leave the city He returned seven weeks postoperatively with a healed, dry ear he required no further care

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535 Park Avenue

AMERICAN BOARD OF OTOLARYNGOLOGY

The American Board of Otolaryngology will conduct only one examination in 1958, and this will be October 6-9, 1958, in Chicago, Illinois, at the Palmer House.

For further information address Dr Dean M Lierle, Secy-Treas, University Hospital, Iowa City, Iowa

trouble A radical mastoidectomy was performed with primary closure of the wound Healing was complete, and the patient was discharged after one month

Case 2 A 46 year-old woman with poor bone conduction in the affected ear Cholesteatoma was present with destruction of the drum and ossicular chain Since an open cavity would serve no logical purpose in this case a radical mastoidectomy was performed with primary closure At the end of five weeks this patient had a dry healed ear (see Fig 11)

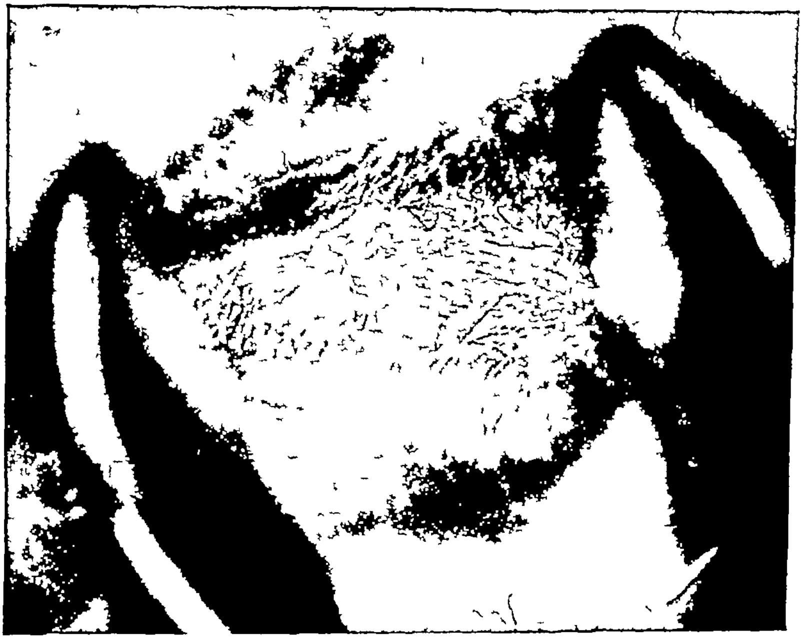

Fig 11 Primary healing in a typical case one month postoperative is shown

Case 3 An 8 year old boy Cholesteatoma was present in the affected ear after a long history of ear trouble with repeated antibiotic treatments Removal of the soft infected cells in the mastoid area, which are typically found in these ears left a huge cavity after the radical mastoidectomy In my experience this type of large cavity in children, has proven to be extremely difficult to heal With the primary closure technique the healing was complete in four weeks As is natural for a boy of his age he is very much interested in swimming His parents have been told that he may swim without concern for his ear

Case 4 A 33 year old business man who came to New York from South America for revision of a radical mastoidectomy which had been performed in Hungary at the age of six There had been suppuration from the ear since his childhood The Eustachian tube was open to the cavity, which contained infected polypi and granulation tissue Bone conduction was poor, and he had had no hearing in the affected ear since early youth The patient had normal hearing on the opposite side The cavity

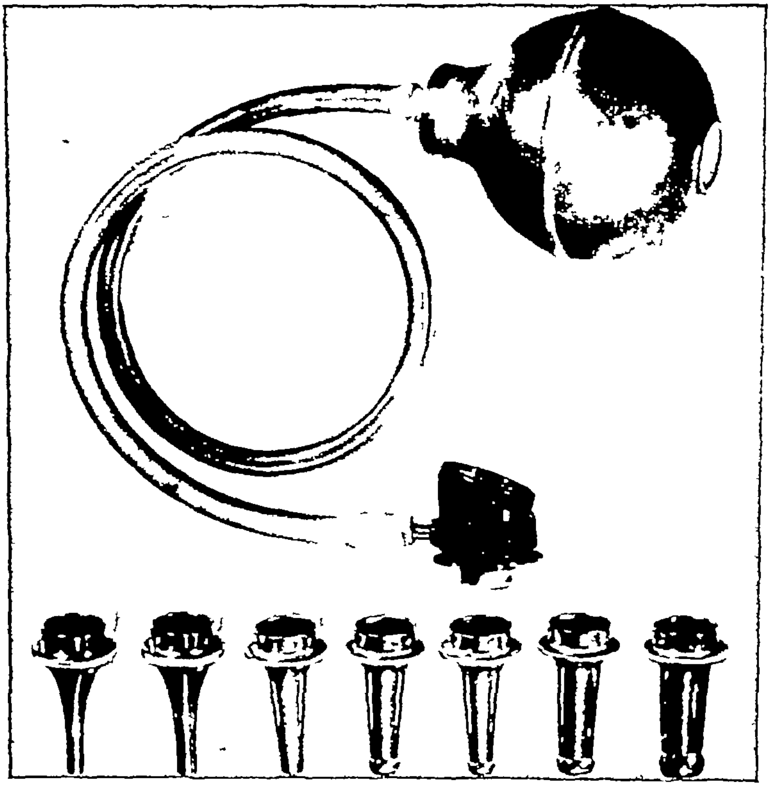

Fig 1 Pneumatic otoscope with specula of seven sizes which permit its use in a patient of any age This is essential for the diagnosis of middle ear effusion

ache has not done his duty unless, after pain and fever subside, he determines whether or not the hearing has returned to normal

DIAGNOSIS

Given a patient with a conductive hearing loss, the physician should suspect the presence of fluid in the middle ear Inspection of the drum reveals moderate retraction Often the drum has an amber color Occasionally a fluid level will be seen, and sometimes one will see bubbles of air in the fluid if it is of the serous type The most important single diagnostic method, which in my experience is almost infallible,

MIDDLE EAR EFFUSION—SYSTEMIC FACTORS[*]

F W Davison, M D,[†]

Danville, Pa

This clinical entity has many synonyms, including secretory otitis media, non-suppurative otitis media, serous otitis media, catarrhal otitis media and hydrotympanum It is a common condition, our department treats more than 300 cases each year There is much disagreement in the literature regarding etiology and treatment In an effort to clarify my own ideas, I have analyzed the case histories of 100 patients who had non-suppurative fluid in the middle ear demonstrated by myringotomy and aspiration

SYMPTOMS

The most common symptom is a conductive-type hearing loss, shown by pure tone audiometry and tuning fork tests It is important to have bone conduction tests, because there is nothing characteristic about the shape of the audiometric curve by air, but a high tone loss is not uncommon If the disease is unilateral, the Weber test is referred to the ear with poor hearing Most of the patients had a blocked or full feeling in the affected ear, the typical history states that the symptoms developed following an acute nasopharyngitis

Most acute middle ear infections respond promptly to administration of antibiotics, but in many cases hearing loss due to fluid in the middle ear persisted until the fluid was removed from one to six months later I think the increased number of patients with hearing loss owing to middle ear effusion is due to the fact that too many physicians do not utilize myringotomy, as well as antibiotics, for treatment of acute otitis media The physician treating a child with ear-

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[*] Read at the Sixty-First Annual Meeting of the American Laryngological Rhinological and Otological Society San Francisco Calif May 22 1958

[†] From the Department of Otolaryngology The George F Geisinger Memorial Hospital and Foss Clinic Danville Pa

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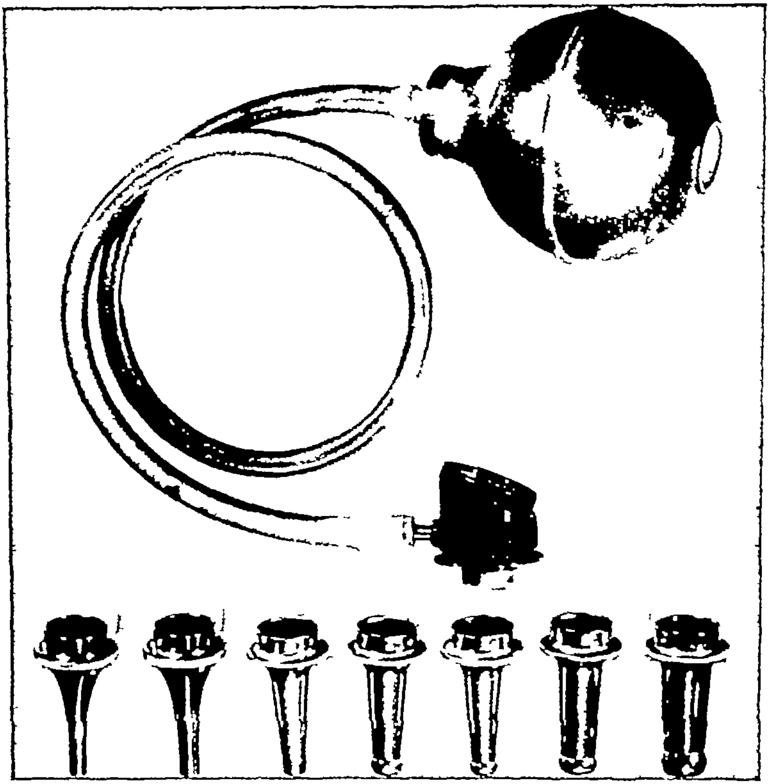

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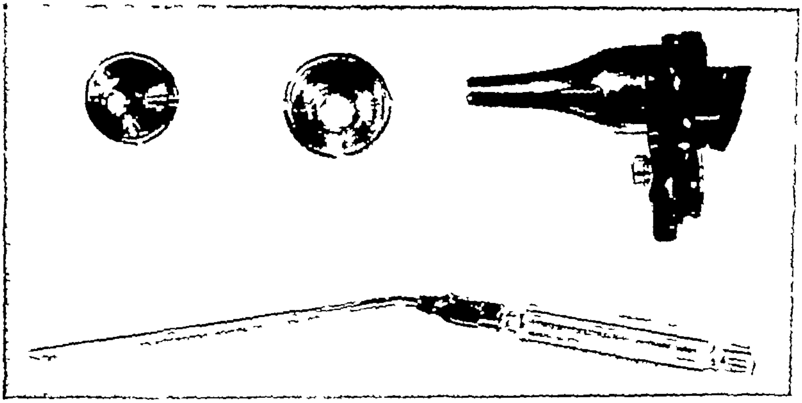

Fig 2 Aural magnifier very helpful when doing a myringotomy and 15 gauge aspirating tip

In order to use the Siegle type pneumatic otoscope effectively, one must have a speculum that fits the canal snugly I use specula of seven sizes

It is not necessary to use a Eustachian catheter for either diagnosis or treatment If one suspects fluid in the middle ear, diagnostic myringotomy and aspiration should be utilized If correctly done it is almost painless, and can be done without anesthesia, either general or local, if the doctor has the patient's confidence One patient had learned how to obtain relief by puncturing his own drum with the point of a sharpened toothpick

ETIOLOGY

I acknowledge with pleasure the fact that my interest in this subject was stimulated by Gordon Hoople's[2] article entitled, "Otitis Media with Effusion, a Challenge to Otolaryngology," published in the May-June, 1950, issue of the Transactions of the American Academy of Ophthalmology and Otolaryngology Most of the important facts regarding middle ear effusion can be found in Dr Hoople's article

I call your attention to one of Dr Hoople's paragraphs, which reads as follows "It should not be forgotten that the diagnostic endeavors should be directed not only to the ear, but to the discovery of *general conditions,* which are abnormal"

It seems self-evident that treatment to be effective must be directed at the etiology It has been said that anything which causes Eustachian tube obstruction, either partial or complete, can cause middle ear effusion, but there are many causes of middle ear effusion and *two or more factors* may be operative in any one patient.

Etiologic factors may be divided into two classes *1* Local, and *2* Systemic All too frequently we have been concerned chiefly with the local factors, especially hyperplastic lymphoid tissue

My experience agrees with that of Baron[1] who says that, "A clean, careful surgical removal of nasopharyngeal lymphoid tissue is better than radiation," however, in only 50 per cent of these 100 cases was careful adenoidectomy a complete answer to the problem Eleven of these patients, after coming to us for treatment, required a second adenoidectomy, and one required a third

The patient who has only one or two recurrences of middle ear effusion per year when he has an acute upper respiratory infection, has no serious problem The patients whose charts

I analyzed had two or more recurrences per year The apparent etiologic factors are listed in Table I

TABLE I—APPARENT ETIOLOGIC FACTORS

		Cases
1	Hypertrophied adenoid or recurrent lymphoid tissue in the nasopharynx	53
2	Recurrent acute nasopharyngitis (Seven of these had hypogammaglobulinemia)	36
3	Allergy	18
4	Hypothyroidism	11
5	Obesity	9
6	Carcinoma of the nasopharynx	1

LARGE ADENOID AND RECURRENT LYMPHOID TISSUE IN THE NASOPHARYNX

Our experience agrees with that of Perlman,[3] who stated that there is no correlation between the size of the adenoid mass and the presence of middle ear effusion His illustrations (Figs 3-6) show the large amounts of glandular, fatty and lymphoid tissue in close relation with the Eustachian tube, and suggest that an excess amount of any of these tissue elements may produce tubal obstruction Thoughtful reading of Perlman's article will, I think, discourage anyone from using a Eustachian bougie, or from advising the use of a radium applicator

Fifty patients who had their adenoids removed stopped having recurrences of middle ear effusion Ten patients who had recurrent lymphoid tissue in the nasopharynx and recurrent middle ear effusion were treated with X-ray therapy In nine out of ten cases X-ray therapy failed to prevent recurrent middle ear effusion It seems obvious that we should consider the *causes* of lymphoid hyperplasia and not confine our efforts to surgical removal or X-ray therapy Hypertrophied lymphoid tissue, considered as a local factor, may be due to repeated attacks of adenoiditis or nasopharyngitis, but the abnormal susceptibility to infection is often due to a systemic factor, such as adrenocortical insufficiency or hypogammaglobulinemia, so it is very difficult to be sure

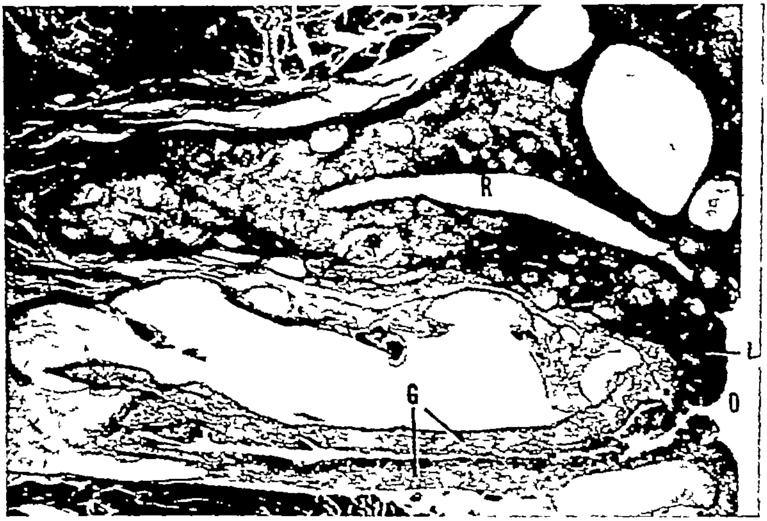

Fig 3 Section through the mouth of the tube (0) and Rosenmuller s Fossa (R) Note the large number of glands (G) along the tube and the lymphoid tissue in the Rosenmuller s Fossa on the torus (L) and at the opening of the tube (Courtesy of Dr H B Perlman)

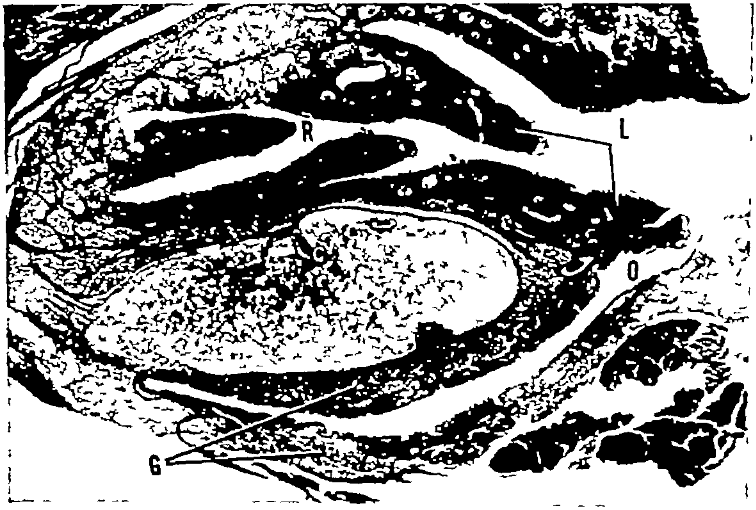

Fig 4 Shows the tube lined by glands (G) Rosenmuller s Fossa (R) containing large amount of lymphoid tissue (L) continuing over the torus at the opening of the tube (O) (Courtesy of Dr H B Perlman)

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TABLE II —ONE HUNDRED CASES OF MIDDLE EAR EFFUSION

	Cases
1—10 years	65
11—20 years	16
21—30 years	6
31—40 years	4
41—50 years	3
51—60 years	2
61—70 years	2
71—80 years	2
Sixty males forty females	Total 100

This table, showing that 65 per cent of these patients are in the first decade, suggests two etiologic factors

1 Poor immunity mechanisms, known to be more common in childhood

2 Hyperplastic lymphoid tissue, known to be more common in childhood

The influence of hormones on lymphoid tissue is shown by normal involution at the time of puberty This suggests that the great enlargement of lymphatic structures, frequently seen in early childhood, may be due to insufficiency of steroids, either gonadal or adrenocortical White[6] points out that there is a marked decrease in the size of lymphoid tissues in response to administration of adrenocortical hormones, and that patients having Addison's Disease have marked enlargement of all lymphoid tissues

Diet is another factor to be considered In our experience, a high carbohydrate diet in childhood causes an overgrowth of lymphoid tissue

Yoffey and Courtice[7] state that the total amount of lymphoid tissue in the body is about 1 per cent of the body weight, so in removing tonsils and adenoids we are removing only a small fraction of the total lymphoid tissue

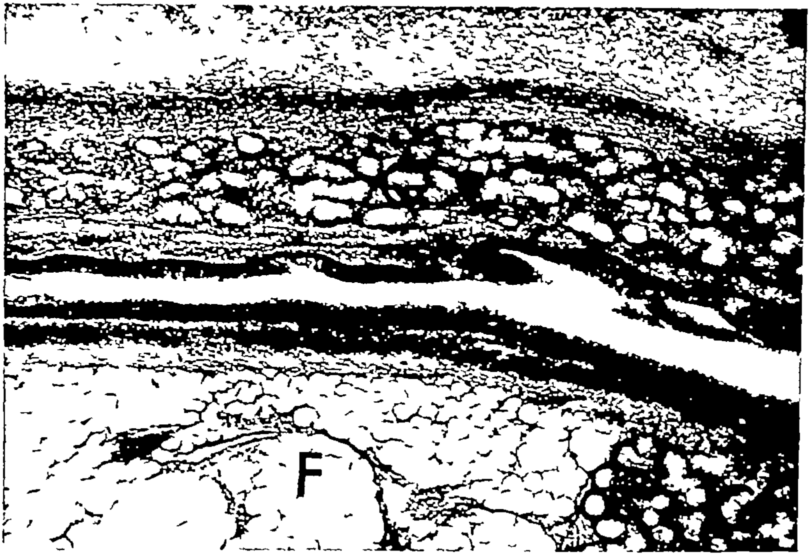

Fig 5 Photomicrograph through the cartilaginous portion of the tube showing the large amount of fat and glandular elements along the walls of the tube These tissue elements are probably important in tubal function and are particularly resistant to radiation (Courtesy of Dr H B Perlman)

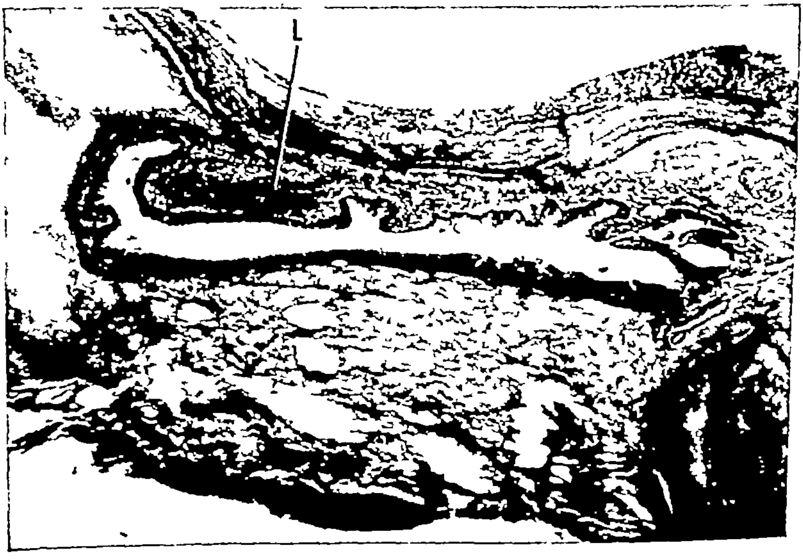

Fig 6 Section through the Eustachian tube above the torus showing mucous membrane folds and the subepithelial lymphoid tissue (L) which may influence tubal function (Courtesy of Dr H B Perlman)

that four of their twelve patients having Gamma globulin deficiency were also allergic, and two of these required specific allergic therapy in addition to Gamma globulin in order to control the main presenting symptoms This is a clearly written concise article, which helped to focus my attention upon the importance of recognizing Gamma globulin deficiency in patients who are infection-prone

There are, of course, other factors which cause an individual to be infection-prone, namely overnutrition, undernutrition, poor adrenocortical function, poor thyroid function and deficiencies in the properdin system,[4] about which we are just beginning to learn

NASAL ALLERGY

The 18 individuals in this group had either food or inhalant sensitivity or both, demonstrated by history, skin tests and response to treatment All of the patients in this group had had previous adenoidectomy but continued to have recurrence of middle ear effusion until the allergic factor was recognized and treated by either avoidance of hyposensitization

HYPOTHYROIDISM

The group of 11 patients with clear-cut hypothyroidism all responded well to administration of either dessicated thyroid or to triiodothyronine. The diagnosis was suggested by the usual signs and symptoms, and was confirmed by laboratory tests showing low protein bound iodine and high serum cholesterol levels One patient, a woman aged 67, who had a very large adenoid which Dr Cole, my associate, removed, had a PBI of 3 03 mcg and a cholesterol level of 302 mg per cent She responded well to adenoidectomy and administration of dessicated thyroid She had previously been told to get rid of her dog and parakeet because the edematous state of her nasal mucosa suggested an "allergic" etiology

The X-ray bone age is useful for diagnosing hypothyroidism in children One youngster, aged nine, had been wearing a hearing aid for three years Her X-ray bone age was reported as six years Bilateral myringotomy and aspiration

RECURRENT ACUTE NASOPHARYNGITIS

This group of 36 patients is composed of those who had previously had an adenoidectomy, but who continued to have attacks of middle ear effusion each time they suffered an acute upper respiratory infection This group might well be called the "infection-prone" group of patients, because they had from three to twelve upper respiratory infections per year, often with high fever and sometimes with complications It seems obvious that there is some systemic deficiency which makes individuals in this group abnormally susceptible to infection After we began looking for it, we found seven individuals in this group who had hypogammaglobulinemia, according to our standards This diagnosis will bear some discussion, because there are those academic purists who do not use this term unless the Gamma globulin levels are extremely low According to our laboratory, the normal range of Gamma globulin is 0 7 to 2 1 gm per 100 cc , as determined by filter paper electrophoresis The Gamma globulin determinations for these seven patients, all of whom were children under ten years of age, were 0 66 gm or 10 per cent, 0 55 gm or 8 per cent, 0 75 gm or 11 per cent, 0 8 gm or 12 per cent, 0 54 gm or 8 per cent, 0 54 gm or 7 per cent and 0 61 gm or 10 per cent A figure frequently quoted in the literature as normal Gamma globulin is 15 per cent of the total serum protein

According to our standards all of these youngsters were deficient in Gamma globulin All of them continued to have frequent recurrences of respiratory infection followed by middle ear effusion despite adenoidectomy, vaccine therapy, allergic management, X-ray therapy and multiple courses of antibiotics, *until* Gamma globulin was administered by intramuscular injection once a month in quantities ranging from 3 to 5 cc , depending upon the age of the patient Our experience suggests that a Gamma globulin level below 1 gm per cent predisposes to frequent infections, and that these patients benefit by administration of Gamma globulin

Four of the seven children who had hypogammaglobulinemia also had allergic symptoms Turner and Dobson[5] reported that four of their twelve patients having Gamma globulin deficiency were also allergic, and two of these required specific allergic therapy in addition to Gamma globulin in order to control the main presenting symptoms This is a clearly written concise article, which helped to focus my attention upon the importance of recognizing Gamma globulin deficiency in patients who are infection-prone

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Four of the seven children who had hypogammaglobulinemia also had allergic symptoms. Turner and Dobson reported

5 Recurrences will be frequent until the systemic causes of lymphoid hyperplasia are found and corrected

6 A careful, visually guided surgical adenoidectomy stops recurrences in only 50 per cent of these cases

7 X-ray therapy to the nasopharynx stopped recurrences in only one of ten cases treated

8 Multiple etiologic factors are present in at least 50 per cent of these cases

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promptly restored her hearing Her thyroid deficiency was at first corrected by triiodothyronine and then dessicated thyroid was used as maintenance therapy Her hearing gain has been maintained

OBESITY

Patients in this group of nine continued to have middle ear effusion until they could be induced to reduce their weight by means of low carbohydrate diet The obese person has excess fatty tissue compressing the lumen of the tube The overweight factor can be readily overlooked unless the doctor is willing to take the height and weight of the patient and compare it with the height weight table This simple measure should not be beneath the dignity of any otolaryngologist who considers himself a physician None of these nine patients was demonstrably hypothyroid, but four of the 11 hypothyroid patients were obese, and carbohydrate restriction was urged in addition to administration of thyroid

TUMOR OF THE NASOPHARYNX

There happened to be only one patient in the total number of 100 who had a carcinoma of the nasopharynx This case reminds us that we should be alert to suspect tumor of the nasopharynx in any adult who has middle ear effusion

SUMMARY AND CONCLUSIONS

1 Middle ear effusion is a common condition

2 A Siegle type pneumatic otoscope is the most important diagnostic instrument

3 Recurrent nasopharyngitis and hyperplastic lymphoid tissue in the nasopharynx are the apparent local etiologic factors in most cases

4 Recurrences will be frequent until the systemic deficiencies responsible for the infection-prone status are corrected One of these frequently overlooked is Gamma globulin deficiency mid-line approach through the thyroid cartilage is used, and in providing for greater accuracy in dividing the contralateral cord and ventricular band, furthermore, removal of the anterior segment of thyroid cartilage in continuity provides an additional margin of safety in lesions approaching or beginning to cross the anterior commissure

The term "extended fronto-lateral" seems appropriate in describing an adaptation of this technique to lesions of somewhat greater extent, such as those showing, *a* posterior extension to or beyond the tip of the vocal process, but not into the posterior commissure, *b* beginning impairment of motility without actual fixation of the cord, *c* limited and superficial extension to ventricle or margin of ventricular band, or *d* subglottic extension amounting to no more than a few millimeters Such lesions are removed *en bloc,* along with a large portion of thyroid cartilage with or without the entire arytenoid, on occasion a horizontal or vertical segment of the cricoid may be included

Post-operative webbing and stenosis are minimized by careful forward suturing of the mucosal edge on the contralateral side, the use of a mold (foam-rubber covered with latex, or acrylic), or immediate skin grafting with insertion of a latex-covered foam-rubber mold The principles in the latter are those described by Erich[2] in the treatment of chronic laryngeal stenosis and subsequently by Figi[3] in the treatment of carcinoma

Obviously careful evaluation of the gross extent of the lesion is required before a decision can be made as to the most suitable type of operation Motility is best studied by indirect laryngoscopy On direct laryngoscopy, the use of a forward telescope is helpful in determining the antero-posterior extent (magnified image), the for-oblique and right-angle telescopes, along with planigraphy, are useful in detecting sub-glottic extension

TECHNIQUE

1 Anesthesia Initially, procaine 1 per cent infiltration of

TECHNIQUE OF EXTENDED FRONTO-LATERAL PARTIAL LARYNGECTOMY *†

CHARLES M NORRIS, M D ,

Philadelphia, Pa

Until recent years, the procedure of laryngofissure (thyrotomy) was the only type of partial laryngectomy widely used, however, it is now quite well established that certain lesions, formerly thought unsuitable for any procedure less than total laryngectomy, because of location or extent, may be treated by other forms of partial laryngectomy without appreciable increase in recurrence rate

In the type of laryngofissure commonly used, excision of one cord, ventricle and portion of ventricular band is accomplished following sub-perichondrial separation of these structures from the inner surface of one thyroid ala Portions of the corresponding thyroid ala have at times been removed simultaneously, since this has appeared to favor return of voice (Jackson[4]) The "anterior commissure" technique of Jackson has been useful in cases where resection of the anterior portions of the contra-lateral cord and ventricular band in continuity has seemed advisable, however, in these circumstances, present trends in technique favor removal of an anterior vertical segment of thyroid cartilage, left attached to the soft tissues being removed

This variation in technique is exemplified by the operation of Cerf,[1] the "bi-lateral thyrotomy" of Kemler,[5] and the "fronto-lateral" operation as described by Leroux-Robert[6] The latter term seems to be an accurately descriptive and desirable one All of these techniques are advantageous in avoiding the hazard of inadvertent division through the anterior commissure and/or the lesion, which may occur when a

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†From the Department of Laryngology and Broncho-Esophagology (Chevalier Jackson Clinic) Temple University Hospital and School of Medicine

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teriorly through the upper portion of the ventricular band to the arytenoid

9 Posteriorly, the excision is completed by extending the superior line of excision downward behind the arytenoid (if the arytenoid is to be removed) or through the base of the vocal process Strong forward traction (the crico-arytenoid joint capsule and inferior cornu having been previously incised) will facilitate inclusion of an adequate margin of normal tissue posteriorly when the arytenoid is to be removed in continuity

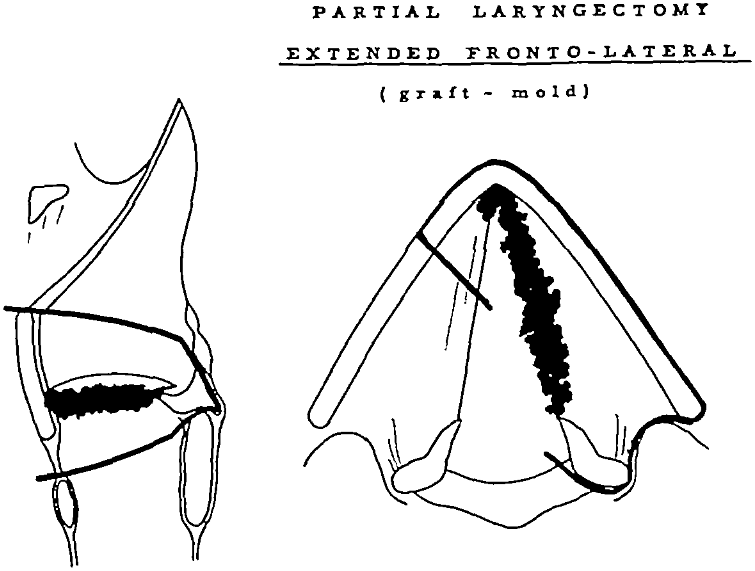


Fig 1 Extended frontol-lateral type of partial laryngectomy Usual lines of excision are shown in saggital and horizontal planes

10 The type of repair is naturally determined by the extent of excision required *a*. If less than one-third of the contralateral cord and ventricular band have been included in the excision, the mucosal edge on this side is anchored forward by horizontal mattress sutures of No 00000 chromic catgut brought through the external perichondrium of the remaining portion of thyroid ala A cylindrical foam-rubber mold subcutaneous tissues in midline from hyoid to supra-sternal notch

2 Vertical incision in the mid-line from hyoid to suprasternal notch Exposure of trachea (by division of thyroid isthmus if necessary), tracheostomy and insertion of endotracheal catheter with inflatable cuff well below the cricoid level General anesthesia is then induced (pentothal and nitrous-ether-oxygen)

3 Vertical division of thyroid ala on contra-lateral (uninvolved or least involved) side, 6 to 12 mm from the midline This is accomplished with the circular saw, attempting to divide only cartilage or cartilage and inner perichondrium

4 Vertical division through crico-thyroid membrane, contra-lateral cord and ventricular band This may be along the same line as the division of the cartilage or further posterior, in which case limited dissection beneath the perichondrium underlying the mid-portion of the cord and ventricular band is first required

5 The lesion is carefully inspected and its gross limits verified

6 External perichondrium is separated from outer surface of thyroid ala on the involved side, as far as the posterior border and from upper to lower borders

7 Inferiorly, the line of excision is usually carried along the upper edge of the cricoid arcus and as far posterior as the crico-arytenoid joint capsule, which is incised if the arytenoid is to be removed The inferior cornu of the thyroid ala is separated from its attachment to the cricoid, on the outer surface of the lamina During this part of the dissection care must be exercised to avoid entering the thin-walled pyriform sinus A horizontal segment of the cricoid arcus and lamina may be included if necessary

8 Superiorly, the line of excision is usually at the upper border of the thyroid ala, although a horizontal segment of the upper portion of the ala is often left *in situ* for support The soft tissues are divided along a line downward and pos-

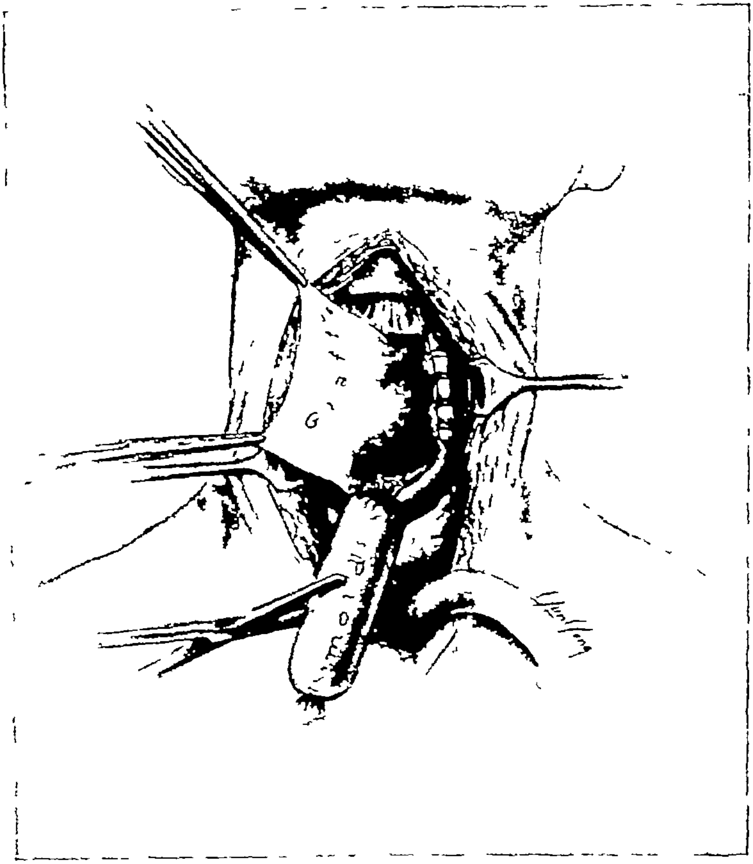


Fig 3 Extended fronto-lateral technique of partial laryngectomy Placement of split-thickness skin graft is shown Following introduction of the latex-covered foam-rubber mold the free anterior portion of the graft is brought across the anterior surface of the mold and sutured to the external perichondrium of the remaining portion of left thyroid ala.

contralateral cord and ventricular band have been removed, or if the arytenoid on the side of greatest involvement has been included, a split-skin graft about 0 015 inches in thickness should be used This is obtained with the Brown electrodermatome, usually from the area just below the clavicle, and is sutured to the mucosal edge posteriorly, above and below on the side from which the thyroid ala has been removed Anteriorly, after repair of the mucosal edge on the contralateral side as above, or suture of a second portion

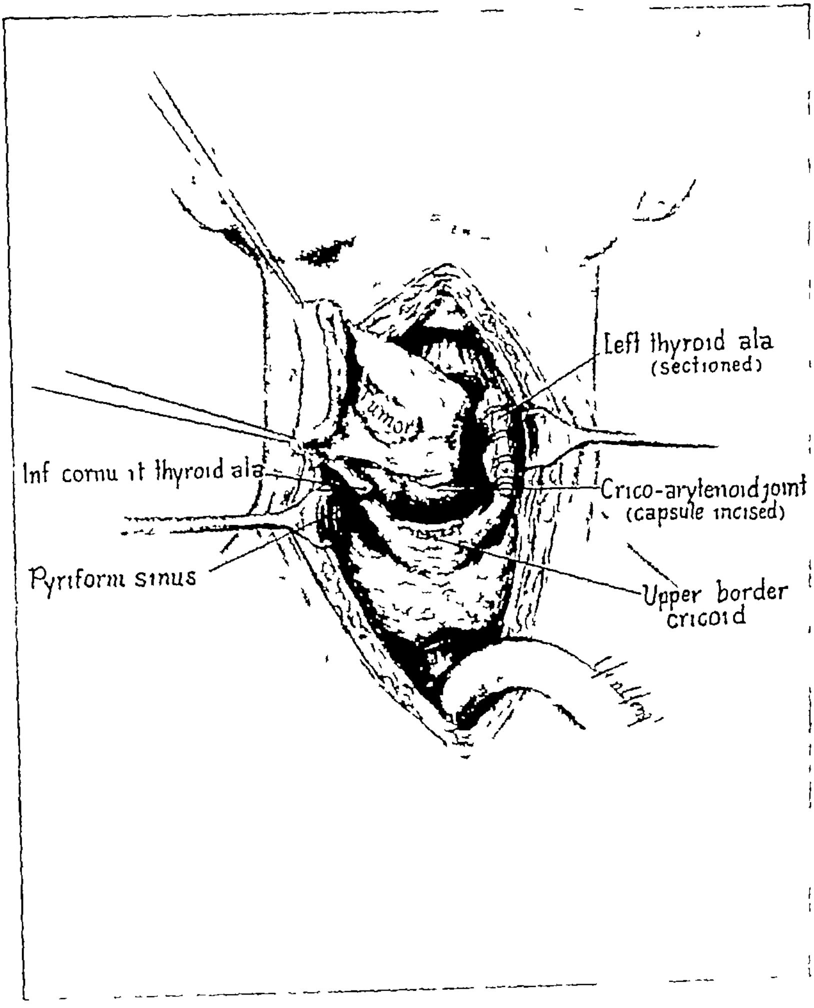
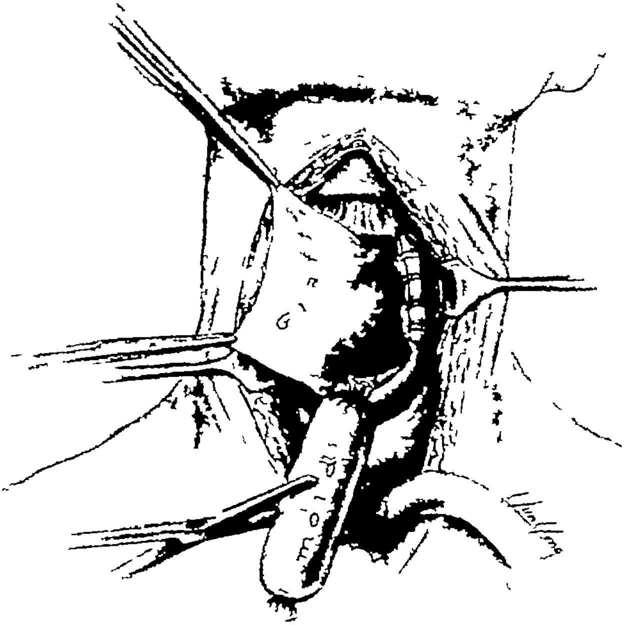


Fig 2 Extended fronto-lateral technique of partial laryngectomy Left thyroid ala cord and ventricular band have been divided and the mucosal edge on this side anchored forward by mattress sutures of No 00000 chromic catgut brought through external perichondrium On the right the inferior and superior lines of excision have been completed, the capsule of the crico-arytenoid joint and the attachment of the inferior cornu of the thyroid ala have been divided

covered with latex (condom rubber) and long enough to extend from the tuberculum of the epiglottis to the first tracheal ring is introduced and anchored in place by two through-and-through sutures of No 32 alloy steel wire Laterally and anteriorly, the mold is covered by the external perichondrium of the ala which has been removed *b* If greater portions of



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11 The endotracheal catheter is removed, a No 6 tracheal cannula introduced, and any accumulated tracheobronchial secretions aspirated In closure, drainage is not used, except for that provided around the tracheal cannula, where the edges of the incision are brought together rather loosely

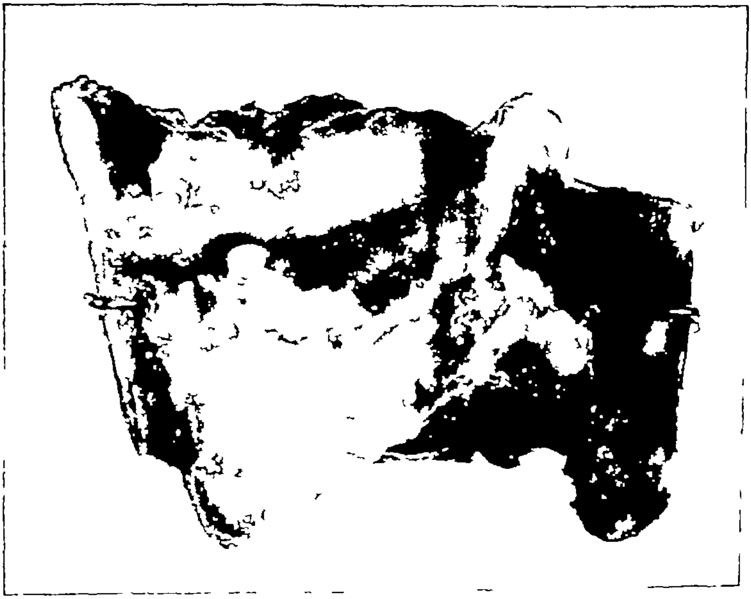

Fig 4 Representative surgical specimen removed by the extended fronto-lateral technique On the left are seen the edge of the divided left thyroid ala with corresponding portions of left cord and ventricular band On the right are the posterior border of the lower two-thirds of the right thyroid ala with its inferior cornu The entire arytenoid is included the articular facet being well shown The lesion involves the anterior commissure and entire length of the right cord with extension into the ventricle moderate impairment of motility had been observed Patient living and well after five years

POST-OPERATIVE CARE

The usual measures in the care of the tracheostomy patient are employed (humidification and catheter aspiration of secretions well below the end of the tracheal cannula) If secretions are tenacious, sterile saline 3 to 5 cc is installed through the cannula before each aspiration Nebulization of detergents such as Alevaire® or mucolytic agents and instillation of gomenol 10 per cent are useful in prevention of crusting The nursing staff should be instructed to report promptly any degree of dyspnea, however mild

With the mold in place, taking of nourishment does not appear to be an important problem Liquids are given for the first 24 to 48 hours, following which soft diet is usually well tolerated Antibiotics (penicillin or penicillin-tetracycline) are given until the likelihood of wound infection has passed, ordinarily about seven to ten days Pre- and post-operative cultures are useful in determining antibiotic susceptibilities, particularly if the hemolytic staphylococcus aureus, coagulase-positive, should be involved Demerol or codeine may be used for local discomfort, but are rarely required after the first 24 hours Ambulation is encouraged on the first post-operative day

The tracheal cannula is changed daily after the first day and the foam-rubber mold removed in about ten days Following removal of the mold, some spill-over of liquids into the larynx may be expected for a few days, and aspiration through the tracheal cannula is continued during this period as needed, to prevent the occurrence of aspiration pneumonitis Once swallowing can be accomplished without appreciable spill-over, the tracheal cannula may be removed, providing the airway seems adequate, after a trial period of corking for one or two days

SEQUELAE

As in other types of partial laryngectomy, the occurrence of excessive granulations may require direct laryngoscopic removal, although this is not likely if the skin-graft remains viable Sequestration of cartilage fragments has not been observed in any of our cases operated by this technique

Adherence of secretions to the area of skin graft has occasionally been noted for a few weeks or months after operation, but may be largely avoided by bedroom humidification

Post-operative stenosis of significant degree occurred in two of the series of 16 cases reported here Tracheostomy followed by insertion of an acrylic mold without re-opening the larynx for periods of ten and 21 days respectively was required, but in both cases decannulation was later accomplished (in 5 and 12 months respectively)

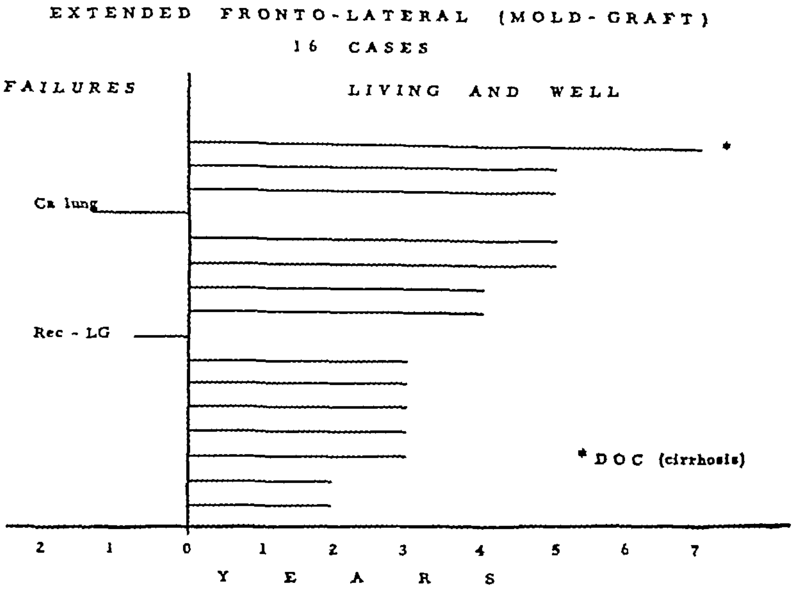

Fig 5 Results in 16 cases of partial laryngectomy by the extended fronto-lateral technique (see text)

RESULTS

Survival data in the 16 cases reported are shown in Table V Of the six patients who qualify for five-year follow-up, five (83 per cent) are apparent cures and one died 16 months after operation, of carcinoma of the lung, without evidence of local recurrence or cervical node metastasis Whether the lung carcinoma was primary or metastatic is undetermined

Of the entire group of 16 cases, only one patient developed local recurrence A laryngectomy was done, and he is living and well after four years There was no operative or post-operative mortality in this series

COMMENT

The frequency with which the "extended fronto-lateral" technique may be applied is not great During the period in which the 16 cases reported were observed, partial laryngectomy by other techniques was performed in 105 cases, *i e*, the relative frequency is approximately 1 7, however, no one would question that these patients, most of whom by previous standards would probably have been treated by laryngectomy, have been given an improved outlook for rehabilitation without appreciable increase in risk of recurrence Although the post-operative voice is, on the average, poorer than following the more limited types of partial laryngectomy, it is usually adequate for ordinary purposes of communication

As in any type of partial laryngectomy, the initial surgical exposure of the lesion should be through tissues known to be uninvolved, and the actual excision performed without haste, the margin of normal tissue surrounding the lesion being in view at all times Prompt healing is favored by preserving intact the perichondrium on at least one surface of all remaining portions of cartilage.

Our present technique differs from that of Figi in that, *1* the split-skin graft is fitted to the mucosal defect and sutured in place, rather than being fixed to the foam-rubber stent which is later to be removed, and *2* we have not found it necessary to insert routinely a second mold immediately following removal of the first, as described by Figi

Since all of the lesions treated in this series were essentially of the intrinsic type, or of only slightly greater extent, radical neck dissection was not performed In none of the cases were cervical nodes palpated initially, and none developed cervical node metastasis after operation

The "hemi-laryngectomy" of Gluck appears to have been largely abandoned as a form of surgical treatment, at least in this country Presumably this is because of the marked post-operative impairment of both the airway and the protective mechanism during swallowing The term "hemilaryngectomy," which implies removal of an anatomic half of the larynx (including cricoid) as described by Gluck, should probably not be used in referring to the type of operation which we have called, in an attempt to be accurately descriptive, the "extended fronto-lateral"

The usefulness of this procedure appears to be in its intermediate position between the more conservative types of partial laryngectomy and total laryngectomy By judicious selection of cases, it is likely that one may avoid, on the one hand, the temptation to treat by conservative operation a lesion which is slightly beyond the accepted indications, and on the other, to resort to total laryngectomy when a less radical operation would be sufficient.

SUMMARY

1 A technique of "extended fronto-lateral" partial laryngectomy is described, and results in a series of 16 cases of carcinoma of the larynx treated by this method are reported

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CARCINOMA OF THE LARYNX

Contralateral Metastasis in Lesions Approaching the Midline[*][†]

NORMAN JESBERG, M D ,

Los Angeles, Calif

Statistical reports of laryngectomized patients are in close agreement as to the rate of recurrence, approximately 30 per cent of patients thus treated develop metastatic cervical lymph-node disease Of this group, approximately 35 per cent may be treated successfully by a secondary radical neck dissection In order to improve our present cure rate, we must consider what happens in these cases which develop cervical lymph-node extension

It is certain that an improvement may be expected by extending the primary operation to include the lymphatic contents of the neck, but the main difficulty is in selecting the cases which may be expected to benefit by such an extended operation Kuhn[1] has given us a statistical report on the types of cases where we may expect metastasis to occur He reported that 57 per cent of all non-cordal and diffuse growths were complicated by metastatic lymph-node disease, and that cordal growths with a moderate extracordal extension ranged up to 34 per cent Approximately 75 per cent of pyriform sinus and 78 per cent of marginal lesions were accompanied by metastasis

One cannot help being impressed by the element of unpredictability in the biological behavior of these growths For example, one patient may have a bulky, primary, extracordal growth without metastasis, and another case with a small cordal lesion may eventually manifest incurable metastatic disease The exceptional cases should not alter our plan of treatment, which is based on statistical probability,

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[*] Read at the meeting of the Western Section American Laryngological Rhinological and Otological Society Beverly Hills Calif Jan 18 1958

[†] From the Los Angeles Eye and Eear Hospital and the Department of Otolaryngology of the University of Southern California School of Medicine

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but we should recognize at the same time that there is a measure of individual behavior in the activity of the disease, the course it takes, and the response to therapy We should anticipate and be *prepared for the unexpected It is not* possible to make an absolute prediction on the basis of statistics, for no two cases are similar in all of the important particulars

Successful treatment by means of an extended surgical approach depends not only on anticipating what lesions may produce metastasis but also on which lymph-nodes may be involved

CLINICAL TYPES OF LYMPH NODE METASTASIS

The usual case developing clinical evidence of metastatic lymph-node disease does so in the first or second postoperative year The customary site is in the nodes of the neck on the same side as the primary growth These cases can be treated with success by a one-stage laryngectomy and ipsilateral neck dissection

In midline growths, such as those of the epiglottis, anterior commissure, interarytenoid space or postcricoid area, there is obviously a potential for bilateral metastasis, and these cases are much more difficult to manage Here one is at a loss to predict the direction or directions of neoplastic extension Until the time when one-stage laryngectomy with bilateral radical neck dissection is more feasible, one must choose either an operation including the laryngeal lesion and the lymphatics of the side of greater involvement, or wide-field laryngectomy alone

Less frequent and less to be expected is contralateral metastasis from a lesion decidedly on one side but approaching the midline Reed[2] has reported this to occur, however, in 10 per cent of the cases developing recurrence after laryngectomy If we include those lesions which produce bilateral metastasis, the figure comes closer to 20 per cent This contralateral metastasis is an occurrence which laryngectomy and neck dissection on the expected side of metastasis would

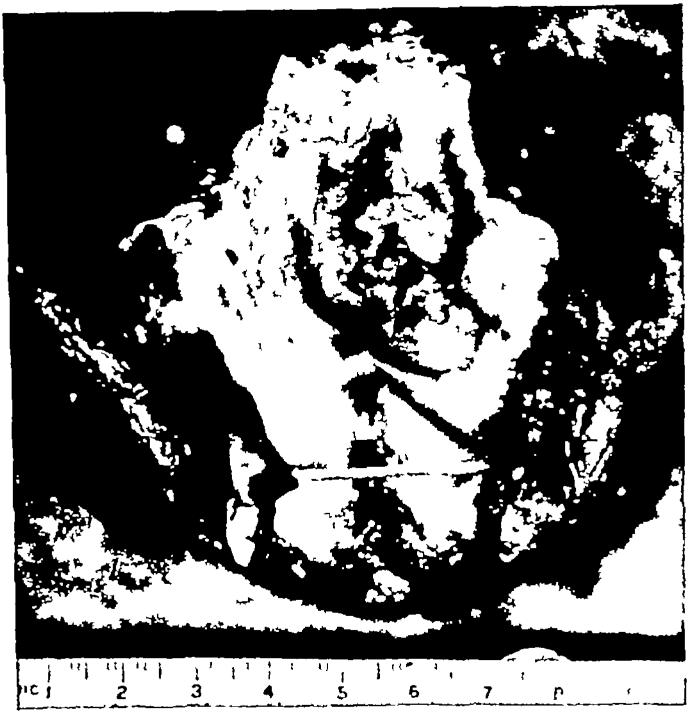

Fig 1 Photograph of the gross pathological specimen showing a large right epicordal growth involving the ventricular band base of the epiglottis and extending to the midline There is a congenital absence of the greater horn of the thyroid cartilage on the right

be powerless to cure I have had two cases which presented this problem

CASE REPORTS

Case 1 C H a 66 year-old white male was first seen April 3, 1951 and complained of progressive hoarseness of one-and a half year s duration and increasing difficulty in breathing and pain around the right ear of two months duration Examination of the ears was negative Examination of the larynx showed a large proliferating neoplastic lesion of the right ventricular band and base of the epiglottis The breath space was narrowed so that the true vocal cords could not be visualized There was no palpable cervical lymphadenopathy

Tracheotomy followed by laryngoscopy and biopsy was done The biopsy report was transitional epidermoid carcinoma Grade II Wide-field laryngectomy was performed under local anesthesia on April 30 1951 The surgical specimen is shown in Fig 1, and demonstrates a large right ventricular band and epiglottic base lesion which extends to the midline of the epiglottis The entire hyoid bone strap muscles, larynx and upper tracheal rings were removed The only other abnormal finding was that there was a congenital absence of the greater horn of the thyroid cartilage on the right

Convalescence was prompt, and he was discharged from the hospital on the ninth postoperative day He did not learn esophageal speech, due to a marked nerve deafness, but he progressed satisfactorily otherwise

On June 20, 1952, two hard, freely movable, metastatic nodules were palpated under the anterior border of the left (contralateral) sternomastoid muscle The nodules were approximately 2 centimeters and 1 centimeter in diameter Since they were freely movable and since he was otherwise a good surgical risk, a left radical neck dissection was advised This advice was declined, and the patient did nothing until July 6, 1953 when he presented himself for radiological treatment The metastatic neoplastic masses were then large, fixed and attached to the skin, 8000 r were given to the left side of the neck and as might be expected the response was not favorable The metastatic masses continued to get larger, and he died on January 26, 1955 At no time during the three-and a half years he was known to have metastatic disease in the left side of the neck did it become clinically manifest on the right side, the side of the epicordal primary growth

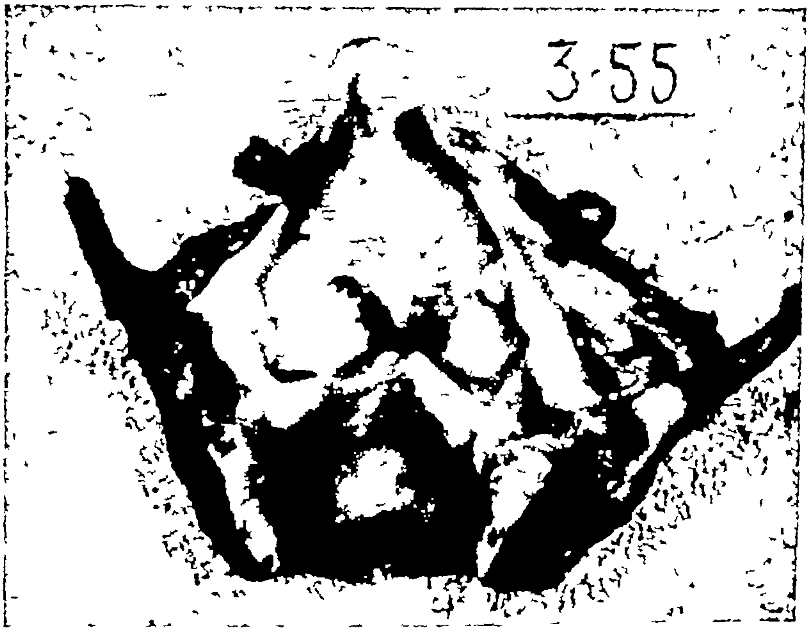

Fig 2 Photograph of the gross pathological specimen showing a growth of the right periarytenoid region extending into the ventricle There is a small cyst just below the anterior portion of the right aryepiglottic fold

Case 2 H V R, an 81 year-old white male, was first seen April 4 1955, and complained of hoarseness of six weeks duration He had been in good general health most of his life but had had a 'slight stroke two years before without any residual symptoms Examination of the larynx showed decreased motility of the right true vocal cord On a subsequent examination, a diffuse surface irregularity was observed around the right vocal process of the arytenoid cartilage and the posterior portion of the true cord Laryngoscopy with biopsy was not done until July 15 1955 at which time there was a diffuse peri arytenoid hemorrhagic, surface lesion extending into the right ventricle The pathological report was squamous carcinoma superficial (ungraded) There was no palpable cervical lymphadenopathy

Wide-field laryngectomy under local anesthesia was done on August 2 1955 The hyoid bone strap muscles larynx and upper tracheal rings were removed The lesion (see Fig 2) surrounded the right vocal process and measured 2x1 centimeters It appeared to be flat and superficial however on microscopic examination there was deep invasion around the right arytenoid cartilage extending into the deep intrinsic musculature It approached but did not reach the midline of the inter arytenoid space The microscopic diagnosis was Grade III epidermoid carcinoma He was discharged from the hospital on the eighth post-operative day and did well until January 1957 when a hard fixed metastatic neoplastic mass was palpated in the area of the left (contra lateral) deep superior, cervical lymph node In view of his age and rather feeble general condition and in view of the fixation a radical neck dissection was not advised He remained comfortable but slowly became worse and died on July 7 1957 Although the solitary metastatic mass in the left side of the neck enlarged at no time was there any clinical evidence of metastatic lymph node disease on the side of the primary laryngeal lesion

DISCUSSION

One could explain contralateral metastasis by the presence of anatomical variations in the lymphatic drainage system, however, Willis[3] has provided us with a pathological explanation, based on the disturbed dynamics of the lymphatic drainage system in the presence of neoplastic disease He suggests that the volume of primary neoplastic tissue may produce an obstruction in the normal lymphatic flow, forcing retrograde carriage of tumor emboli and crossed deposition to the opposite side He further states that this crossed metastasis may antedate lymphatic spread to the ipsilateral side One would expect this to occur in moderate to large volume tumors which approach the midline This was the situation in both of the cases reported In the epicordal case, the lesion was large and extended to the midline In the peri-arytenoid case, the growth appeared to be very superficial, however, on pathological examination it was found to extend deeply around the right arytenoid cartilage, although not reaching the midline posteriorly In each of these cases, a one-stage laryngectomy, with ipsilateral neck dissection, would have failed to encompass the disease

SUMMARY AND CONCLUSIONS

1 A report of two cases of diffuse unilateral carcinoma of the larynx, which produced contralateral metastasis, is presented

2 These cases confirm the incidence of contralateral metastasis previously reported by Reed

3 An explanation for this occurrence, based on retrograde embolic deposition, has been provided by Willis

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AMERICAN ACADEMY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY HOME STUDY COURSES

The 1958-1959 Home Study Courses in the basic sciences related to ophthalmology and otolaryngology, offered as a part of the educational program of the American Academy of Ophthalmology and Otolaryngology, will begin on September 1 and continue for a period of ten months Detailed information and application forms may be secured from Dr William L Benedict, the executive secretary-treasurer of the Academy, 15 Second Street, S W, Rochester, Minnesota Registrations should be completed before August 15

AN OBJECTIVE APPROACH TO THE COMPLAINT, LUMP IN THE THROAT[*][†]

G ARNOLD HENRY, M D ,

Toronto, Canada

Patients complain frequently of a lump in the throat This term sums up for them a number of vague, uneasy complaints which are annoying and, sometimes frightening

The physician in his office, or at the bedside, notes the complaints and clinical findings of his patient, and supplements his knowledge by laboratory studies With this picture in his mind, he may consult the literature

Modern systematized medicine usually assumes the diagnosis and recounts the symptoms, signs and laboratory findings accompanying the condition In many instances, the two pictures are readily superimposed, however, in a complaint such as this, the results are likely to be confusing Without a definite plan of investigation, the physician frequently succumbs to the easy and popular view, and labels the patient a neurotic

A few years ago, the author became interested in this complaint One hundred and seventy-five patients were studied objectively over a five-year period The results of that survey will follow

Reference to the medical texts showed this complaint to be associated mainly with functional disturbances Some authors exercised considerable imagination in determining the causes, others took a more objective approach

Thomson and Negus,[1] in discussing sensory affections of the pharynx, note that hyperalgesia and paraesthesia may lead patients to complain of soreness, irritation, burning, choking, dryness, etc, and a sensation of foreign body in the throat Most cases, they feel, are found among the hysterical and neurotic, but abnormal sensations are also met in the anemic, gouty, dyspeptic, alcoholic and hypochondriac The nose, throat, lingual tonsil, ears, teeth, refractive errors, etc, may be a cause of reflex irritation Lederer[2] says that, in a large proportion of so-called hysterical cases, some local lesion will be found to account for the symptom, if the pharynx is carefully examined

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[*] Read at the Sixty-first Annual Meeting of the American Laryngological Rhinological and Otological Society Inc. San Francisco Calif. May 22 1958

[†] From the Department of Otolaryngology University of Toronto Medical School and St. Michael's Hospital Toronto

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In the literature, Tremble,[3] among others, directed attention to the lingual tonsil Mills[4] reported cases in which the nasal sinuses were the cause Morrison[5] stated that osteoarthritis of the lower cervical spine was a frequent cause of lump in the throat According to Boreadis and Gershon-Cohen,[6] osteoarthritis in the region of the vertebral foramina, with narrowing and roughening, is very important Inman[7] believes there are two separate kinds of sensation one caused by local inflammation over the arthritic process, and the other along the whole length of the peripheral nerve

Lindsay,[8] in discussing functional diseases of the upper swallowing mechanism, notes that a tonic spasm of the pharyngeal musculature may occur in disorders of the central nervous system, such as tetanus or brain injuries, as well as in acute local infections A tonic spasm probably occurs also in some psychogenic disorders (cricopharyngeal spasm, globus hystericus)

Pastore, Aldrich, Richards and Lindsay,[9] in a panel discussion on "A Lump in the Throat," covered the organic, psychic and physiological aspects of the subject

Clerf[10] stated that spasm of the cricopharyngeus frequently may be called a lump in the throat The latter may be caused, also, by organic lesions in the esophagus or by reflex action from more distant parts, associated with pharyngitis, arthritis, or straight autonomic stimulation This latter cause was developed by Hilger,[11] who pointed out that disturbances of the autonomic nervous system cause neurovascular changes in a number of areas These are evident in the hypopharynx as a pain and a lump Sjoberg,[12] in experimental work on cats, showed that a high bilateral vagotomy caused paralysis of the vocal cords and pharyngeal paralysis There was also a strong contraction of the cricopharyngeus and cardiospasm This, he claimed, was due to a sympatheticotonic contraction at both levels of the esophagus

A comprehensive study of the group was carried out under a wide variety of headings These may be arranged as to age and sex, site and duration of the lump, associated complaints, clinical findings, management, treatment and results of treatment Notes were made on the estimated psychogenic element involved in each case

TABLE I—AGE AND SEX OF 175 PATIENTS

Female		116
Under 40 years of age	65	
Over 40 years of age	51	
Male		59
Under 40 years of age	19	
Over 40 years of age	40	

TABLE II—SITE AND DURATION OF LUMP

Site of Lump—	
Cricoid Area	107
Vallecular Area	68
Duration of Lump on First Visit—	
Under 1 month	53
Under 2 months	91
Under 1 year	143
After 1 year	32

It will be noted that two out of three cases in this series were female Contrary to general opinion, they were more likely to be under the menopausal age Males with this complaint were more frequently over forty years of age

The lump was localized most commonly at the cricoid level in the midline In the remainder of the cases, it was situated higher, usually about the vallecular level, to one side or other of the throat Most of the patients were sufficiently impressed with their complaint to seek early advice

Lump in the throat is the expression the patient finds best describes the vague, disturbing sensation which warns him all is not well in this region of his body The associated complaints may be equally difficult to describe

In order of frequency, the following symptoms were noted A feeling of dysphagia, soreness, fullness, and foreign body Cough, hoarseness and bleeding were present in lesser numbers

Dysphagia, to the point of actual interference with the swallowing of fluids or solids, was not common, although occasionally seen with loss of weight It was usually described as difficulty with a dry swallow—their own secretion

TABLE III—ASSOCIATED SYMPTOMS

Dysphagia	60
Soreness Pain	57
Fullness Pressure	43
Feeling of Foreign Body	28
Less frequently—Cough, Hoarseness, Bleeding	

TABLE IV—CLINICAL FINDINGS

Pharyngitis	66
Post Nasal Discharge	37
Cervical Arthritis	23
Esophagitis	21
Malignancy	15
N Y D	30
Foreign body, cysts, elongated styloid process, hyperthyroidism, anemia, alcoholism, tobacco	

Soreness and pain were of a vague, nagging nature, usually about the location of the lump They occurred relatively more frequently in the ventricular area When present at the cricoid level, they occasionally radiated substernally

Fullness was usually associated with those who felt a foreign body or secretion might be present in the vallecular area Pressure was particularly noted in the vallecular area, or in patients with a large thyroid lobe

In order of frequency, pharyngitis, post nasal discharge, arthritis of the lower cervical spine, esophagitis and carcinoma of the hypopharynx and upper esophagus, were the most common findings Found less often were foreign body, cysts, particularly in the vallecula, elongated styloid process, lack of movement of a vocal cord It was noted in patients with hypothyroidism and sideropenic anemia Patients with hyperirritable throats, as well as those who used alcohol and tobacco to excess, were noted in the series

Pharyngitis was the most common finding, noted usually in the lingual tonsil and the region of the lateral pharyngeal bands Recent or active inflammation, rather than hypertrophy, was the important finding Frequently, there was an area of hyperemia in the region of the lateral pharyngeal band just medial to the posterior pillar of the tonsil

In most instances, alleviation of the offending cause by antibiotics or other therapy stopped or relieved the complaint Patients often stated that previous sore throats had caused the same complaint Occasionally, post nasal discharge accompanied the pharyngitis, but the two findings were not regularly associated

Patients with post nasal discharge fell into two groups those with profuse, and those with dry, crusty secretions, such as are frequently seen with a low-grade posterior sinus infection Suppurative antral and ethmoidal infections were a factor in a few cases, and treatment of the sinus infection removed the complaint Patients in the group were temporarily relieved of the lump by swallowing

A number of patients with obvious allergies or irritations to paints, chemicals and detergents were seen who, at times, had this complaint

Arthritis of the cervical spine was observed radiologically in a number of cases The lower three cervical vertebrae were more commonly involved On the whole, other significant findings were not present, although the patients occasionally complained of soreness in the back and sides of the throat and in other areas, such as the shoulders and arms Patients with severe arthritis did not complain of a lump in the throat

A number of patients felt that a foreign body might be present, accounting for their symptoms Where the history warranted, radiological studies and direct examination were carried out Sometimes, in indirect examination of the hypopharynx or direct examination of the esophagus, evidence of injury by a passing foreign body could be seen Only in a relatively small number was a foreign body found It would seem that, for a foreign body to be interpreted as a lump, it must be small and relatively non-irritating Injury to the retropharyngeal soft tissues with thickening may, in its early stages, feel like a lump

TABLE V—ESOPHAGEAL EXAMINATION 42 CASES

Negative		8
Upper Esophageal Cancer		7
Foreign Body Trauma		5
Diverticulum		1
Esophagitis		21
Cricoid and Cardiac Levels	10	
Cricoid Level	9	
Throughout	2	

Two instances will be mentioned briefly to show that these latter factors cannot be ignored A man was sent to my office with a lump in his throat and an accompanying pharyngitis and "flu" ear The night before, while eating a green salad, he had a stinging sensation in his throat Beyond the signs described, nothing further was evident by indirect examination in the region of the hypopharynx A week later, he returned with a greatly swollen arytenoid and pyriform fossa A small metal staple, probably the one used to close the plastic bag containing the greens, was seen on X-ray

The second case was sent to me a week after she had complained of a lump and history suggesting a foreign body There was no longer the complaint of a lump Instead, there was a massive swelling of her lower retropharyngeal tissues A huge, superior mediastinal abscess was drained through the neck.

Forty-two patients were examined esophagoscopically Early upper esophageal cancer, foreign bodies and foreign body trauma, and diverticula were found in a small number of cases to be the cause of the complaint

The remaining cases, constituting half of the group, were labelled esophagitis They did not include inflammatory changes associated wi the first half of the group Ten of the cases showed a circular band of hyperemia and esophagitis extending an inch or more down the esophagus from the cricoid level with a similar diffuse, and usually less apparent, area present at the cardia Nine cases showed esophagitis only at the upper or cricoid level, and included three with web formation Two cases had more or less diffuse esophagitis throughout with the greatest involvement in the upper area

The group with esophagitis at the cricopharyngeus and cardia probably represent spasm at the two levels The second group seemed to be associated with a number of factors, such as reflex spasm, allergic and other irritants, sideropenic anemia

RADIOLOGICAL FINDINGS

Many of these cases had radiological studies including the chest, cervical spine, barium bolus and occasionally, spot films This was carried out in every case before esophagoscopy Studies of the lateral cervical spine showed the soft tissues and largeal cartilages, as well as the cervical spine A number of interesting pictures of osteoarthritis were obtained Barium studies in most cases gave evidence of postcricoidal cancer, although there was a tendency sometimes to miss a fair-sized lesion in this area Definite evidence of cricopharyngeal spasm was not obtained, although, in a few instances, the radiologist suspected a hesitation in the bolus entering the esophagus

The management of a patient with lump in the throat is important. With such a vague complaint, the patient frequently suspects the worst The functional and emotional element is a varying factor in all cases Nearly everyone, when carefully questioned, can relate stresses and strains in their daily life In this series, clinical findings of significant value were found in the majority of cases Treatment of the known causes, with allowance for the overlying functional factor, should be the keynote of therapy

The history and examination must be thorough Treatment will be based on the examination findings Where there is no response to therapy in a month or so, thorough radiological studies should be made If the results are negative and supported by clinical findings, a further waiting period is justified Continuation of the symptoms at the cricoid level or lower should be followed by esophageal examination

As soon as possible, a confident attitude must be struck, and the patient given to understand that the examiner is familiar with his complaint He is told that it is seldom serious and that the necessary steps to safeguard his health have been taken It is well to let him know that, while most patients respond readily, others may have trouble for a considerable period of time The advice of the family physician is available in most cases, the internist is frequently consulted, the neurologist occasionally, and the psychiatrist rarely

The treatment of pharyngitis, inflamed lingual tonsils, lateral pharyngeal bands, postnasal discharge, foreign bodies and injuries caused by their passage, need not be labored Treatment for the hypothyroid and anemic is essential Advice regarding alcohol, tobacco and obesity is important

Esophagoscopy is more than a diagnostic procedure The stretching of the cricopharyngeal sphincter, breaking down of adhesions in arthritis cases, and removal of webs is beneficial The application of dilute silver nitrate seems beneficial in prolonged esophagitis In addition to medication for presenting conditions, thiamin chloride is frequently used, sodium iodide for dry throats and, in cricopharyngeal spasm, antispasmodics

The results of therapy were good in the pharyngitis cases Most cases fell into the cured or improved group, with few failures Improvement usually meant that the patient was cured of the complaint, but that it tended to recur with additional pharyngitis The results were much the same for postnasal discharge

The arthritis group was much harder to estimate, both as to their validity and the result of treatment It should be noted that the diagnosis is made, primarily, radiologically A like group of patients without complaint would, doubtless, show characteristic osteoarthritis Mostly, they were improved, or no better About half of the esophagitis cases were cured, the remainder falling about equally into the improved and the no better category

Patients with a legitimate foreign body or a vallecular cyst treated, did well The vague foreign bodies and the N Y D group were mostly improved, with some cured and others no better

Where the lump was an early symptom of carcinoma or a stenosing lesion, the progress of the patient was that of the disease The complaint, however, became lost in the more serious presenting symptoms

SUMMARY

Lump in the throat best describes the patients' summation of a number of vague complaints in this part of the body Vague symptoms are frequently the reflection of similar clinical conditions which may easily be overlooked

The complaint may be present with pharyngitis, postnasal discharge, moderate cervical arthritis and esophagitis It may occur with early retropharyngeal swelling, reaction to a foreign body lodged or passed, or a cyst in the vallecula When it occurs with new growth or stenosis, it is an early sign Emotional disturbances are capable of causing the complaint, and frequently affect the duration and intensity of the presenting symptoms A number of general systemic conditions play an important part

CONCLUSIONS

There has been a tendency to place the patient with the complaint, lump in the throat, in the realm of the neurotic In many cases, there is a varying element of truth in this belief

An objective approach to the problem uncovers significant clinical findings which are the primary cause in the majority of cases Satisfactory management of these patients embodies practice of the true art and science of medicine

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DOES IRRADIATION OF INFANTS AND CHILDREN CAUSE CANCER OF THE THYROID?*†

Shirley Harold Baron, M.D.,
San Francisco, Calif.

The possibility that cancer of the thyroid in children and adolescents might be related to previous irradiation of the head, neck, or thymus in infancy or early childhood, should be of great concern to otolaryngologists, the majority of whom have prescribed some form of ionizing radiation as an adjuvant in the treatment of recalcitrant ear, nose and throat diseases.

Duffy and Fitzgerald,[1] in 1950, suggested that irradiation of the thymus in infancy might be an etiological factor in cancer of the thyroid in children and adolescents. Clark,[2] in 1955, impressed with this possibility, reviewed his cases of cancer of the thyroid in this age group. He discovered in his 13 cases that all had been subjected to previous irradiation: three, to the upper chest for an enlarged thymus; three, to the neck for cervical adenitis; five, to the head and neck for enlarged tonsils and adenoids; one, to the face and anterior chest for sinusitis and peribronchitis; and one, to the anterior upper chest for pertussis.

Disturbed by this startling report of Clark's, I reviewed two cases of cancer of the thyroid in children that I had seen that year (1955) and found that they both had had irradiation for an enlarged thymus in infancy. Subsequently, I encountered two more cases, and an additional three cases were reported to me by two colleagues. The following are the case reports.

Case 1. D. R.—Female, 18 years of age. Born Feb. 1, 1940. Pertussis Aug. 8, 1940. Chest X-ray Sept. 5, 1940, possibility of an enlarged

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†From the Department of Surgery, Division of Otolaryngology, Stanford University Medical School, and Departments of Otolaryngology, Mount Zion and French Hospitals.

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thymus" Given 204 r of X ray radiation therapy to thymus (102 r, Sept 13 1940, and 102 r, Nov 29 1940) Mass in isthmus and left lobe of thyroid noted on Nov 10, 1951 (11¾ years of age) Surgery done on July 9, 1952 (12 years, 5 months of age) Diagnosis Papillary carcinoma of the thyroid, with extension to the pretracheal fascia and regional lymph nodes, supplementary X ray therapy between July 30 1952, and Sept 5, 1952 X ray chest, Aug 12, 1952, showed pulmonary metastases, which have progressively increased to the present however, patient appears well and has no complaints Interval between irradiation and diagnosis of cancer, 11 years, 10 months

Case 2 S O—Female 12 years of age, born June 11, 1945 Papillary carcinoma surgically removed on April 6, 1954 (8 years, 10 months of age) Supplementary X ray therapy Chest X ray films were clear at that time, chest X rays Dec, 1957, and Mar 1, 1958, suggest metastases Patient appears well and has no complaints

In 1955, when I reviewed this case, the pediatrician stated that this child had had irradiation both to the thymus and nasopharynx, however, in 1958, a record of prior irradiation could not be found, hence, there is no certainty that this patient had had prior irradiation

Case 3 R W—Male 18 years of age Irradiation to thymus for respiratory difficulty at four months of age, mass in thyroid discovered at age 15 Surgery right radical neck dissection and total thyroidectomy for papillary adenocarcinoma Postoperative complication cerebral edema and partial blindness which persists, feels well

Amount of irradiation in infancy could not be obtained, but there is no question that it was given Interval between irradiation and diagnosis of cancer 15 years

Case 4 M M—Female, 11 years of age Irradiation to thymus at eight months of age Total of 800 r (four treatments of 200 r each measured in air) were given in a two week period Jan 5, 1948, using 200 kv 50 cm distance and ½ mm of copper and 1 mm of aluminum filtration Total thyroidectomy and left radical neck dissection, Sept, 1952 (age 5 years 4 months), supplemented with radioactive iodine, Oct, 1952 Diagnosis Alveolar carcinoma of thyroid and regional lymph nodes Present condition feels well but there is evidence of lung and mediastinum metastases Interval between irradiation and diagnosis of cancer 4 years, 9 months

Case 5 S B*—Female, 19 years of age Irradiation to thymus at six months of age Total dose 450 r (150 r, 6/14/39, 150 r, 6/21/39, 150 r 6/28/39), 200 kv 1 mm copper and 1 mm aluminum filter Thyroid surgically removed 16 years of age Diagnosis Adenocarcinoma, patient is asymptomatic at present No evidence of pulmonary metastases, interval between irradiation and diagnosis of cancer 15 years

Case 6 C P*—Male 12 years of age Irradiation of nasopharyngeal lymphoid tissue at about the age of five dose not known Two stage operation for cancer of the thyroid with cervical node metastases *1* Right lobe of thyroid removed and right radical neck dissection, *2* two weeks later left lobe of thyroid removed and partial left radical neck dissection, supplementary therapy with I^{131} At present almost three years later no evidence of neck recurrence or lung metastases Interval between irradiation and diagnosis of cancer 7 years

Case 7 D J—Male 7 years of age Four X ray treatments to the thymus at three months of age exact dose not known Surgery for cancer of the thyroid with metastases to cervical nodes total right thyroidectomy with right radical neck dissection and sub-total left thyroidectomy, supplementary therapy with I^{131} At present two and one-half years later, no evidence of neck recurrence or lung metastases Interval between irradiation and diagnosis of cancer 7 years

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*Reported through the courtesy of Dr William S Freeman Jr

*Cases 6 and 7 reported through the courtesy of Dr Leonard Dobson

REPORTS FROM THE LITERATURE

These seven cases (one doubtful), added to those of Clark, prompted this review of the evidence for and against the possible relationship of cancer of the thyroid in children and adolescents to previous irradiation

Duffy and Fitzgerald,[1] in 1950, reported 28 cases of histologically diagnosed thyroid carcinoma in children and adolescents, 18 years of age or younger Ten cases in this series had been subjected to irradiation to the thymus for obstructed respiratory symptoms ascribed to "enlargement of the thymus" In all cases, these were short courses of low voltage Roentgen rays administered some time between the fourth and sixteenth month of life These authors stated, "to propose a cause-and-effect relationship between thymic irradiation and the development of cancer would be quite unjustified on the basis of data at hand, when one considers the large number of children who have had irradiation to 'enlarged thymus', however, the potential carcinogenic effects of irradiation are becoming increasingly apparent, and such relationships as those of thymic irradiation in early life and the subsequent development of thyroid or thymic tumors might be profitably explored" Seven years later, Duffy[3] stated, "there is strong circumstantial evidence that therapeutic X-irradiation in infants may be an etiologic factor in thyroid cancer of childhood and adolescence"

Simpson, Hempelmann and Fuller,[4] in 1955, reported a study of the subsequent history of 1,400 of 1,722 children who received X-ray therapy to the thymus gland In 17 of these children neoplasia is known to have developed, including seven cases of leukemia and six of carcinoma of the thyroid This is a significantly higher incidence than was found among the untreated siblings of the irradiated children or in the general population In addition, nine treated children were found to have had thyroid adenoma All of these cases of cancer of the thyroid had had an amount of irradiation of 200 *r* or more

Adding to this study, two years later Simpson and Hempelmann[5] brought the total cases traced to 1,502 treated by X-ray and 1,933 of their untreated siblings Of those treated by X-ray the known cases of thyroid cancer increased to 11 Relative to their report of an increased incidence in leukemia, it is noteworthy that Court-Brown and Abbatt[6] reported an increased incidence of leukemia in patients with ankylosing spondilitis treated with X-ray, and Stewart[7] and associates speculated that diagnostic irradiation *in utero* may occasionally cause leukemia or cancer in the unborn child

Winship[8 9] started a survey of childhood thyroid carcinoma in 1948, but not until 1950 did he start to inquire about a history of irradiation In his report of 275 cases in 1955,[8] Winship stated, "Counting all the known cases in the United States of childhood carcinoma of the thyroid, almost 20 per cent have had irradiation of the thymus gland or to the neck for some other disease This is a significant percentage"

Majarakis, Slaughter, and Cole,[11] in 1956, recorded 15 cases of cancer of the thyroid in children and adolescents between five and 20 years of age Ten of these had a history of irradiation to the head and neck between two months and six years of age, with doses ranging from 200 *r* to 625 *r* In this group of nine females and six males, the interval between the therapy and the diagnosis of cancer was approximately 7 8 years

Frantz[12] told of two cases of carcinoma of the thyroid, one following irradiation for the keloid of a burn scar and the other for a giant tongue Cancer developed after 10 years in one and 15 years in the other The radiation in each case was in small doses

In 1956, Fetterman[13] reported ten cases of thyroid carcinoma in children under 16 years of age Eight of these had received prior irradiation, two for hemangiomas of the upper face and chest, two for enlarged lymph nodes, one for enlarged tonsils, and three for a presumably enlarged thymus Fetterman emphasized the importance of repeated questioning which doubled the number in his series known to have been previously irradiated, that is, in four of his eight cases a discovery of previous irradiation was made only after repeated questioning Fetterman suggested that, in the series of Ravdin and Horn,[14] and of Warren and associates,[15] more pointed questioning might have elicitied information that there had been previous irradiation in a higher percentage of cases Klopp,[16] too, felt that the incidence of previous irradiation in childhood thyroid cancer would be even higher if more correct information could be obtained by more careful questioning He related the story of one case in which previous irradiation had been denied by the patient and the father, but later information from the divorced mother in another city revealed that the patient's thymus had been irradiated in infancy

In an article from the Johns Hopkins Hospital, which is in the process of publication with Dr Samuel Asper[17] as the principal investigator, the following is being stated [27] "In a survey at the Johns Hopkins Hospital, there were found 40 thyroid carcinomas in people under 25 years of age, 17 of these had received X-ray therapy of some kind Of the 17, six had so-called cross-fire X-ray of the tonsils, two had X-ray of the tonsils and nasopharynx, four received X-ray to the thymus, two, X-ray for acne of the upper back and face, one, X-ray for an enlarged tongue, one, X-ray for a laryngeal polyp, and one received treatment by radium pack over a hemangioma, which presented over the inner portion of the clavicle

Notwithstanding all this evidence, there are a number of factors which have been presented in opposition to the belief that there may be an association of irradiation in infancy to carcinoma of the thyroid In an editorial in the *British Medical Journal*,[18] referring to the reports of Rawson and associates[19] and Bielschowsky,[20] it is stated "It could be argued, however, that the thyroid cancers in the treated children were not caused directly by the irradiation, but were in some way due to the destruction of the thymus There is evidence (Rawson, et al) that the thymus may be one of the sites of removal of circulating thyrotrophic hormone Since thyrotrophic hormone is known to play a part in the development of cancer of the thyroid (Bielchowsky), it is conceivable that the destruction of the thymus might in itself do something to provoke cancer of the thyroid by increasing the amount of thyrotrophic hormone in the blood " Counteracting this speculation is the number of thyroid cancer cases in which the previous irradiation did not involve the thymus

It is possible, too, that some of the thyroid cancers, thought to have developed after irradiation, might have been present before the irradiation Winship[10] pointed out that in his collected series of 400 cases of carcinoma of the thyroid in children, 12 had tumors at birth, these subsequently proved to be carcinomas Uhlmann[21] told of a patient who failed to respond to X-ray therapy for enlarged cervical lymph nodes, two months after treatment a biopsy revealed metastatic carcinoma of the thyroid

Uhlmann,[21] in a study of 25 patients under the age of 21 who had been referred to him for treatment of carcinoma of the thyroid during 18 years between 1938 and 1956, found that only four had had previous irradiation During the same 18 years, he administered radiation therapy to 2,500 children for hypertrophic lymphoid tissue in the pharynx and for enlarged tonsils In a follow-up of only 480 cases of these, not a single instance of carcinoma was found during a period of seven years Uhlmann measured the amount of radiation that reaches the thyroid during X-ray treatment for benign hyperplasia of the nasopharynx His customary three treatments, with a total of 375 *r* to each of two lateral fields, resulted in a maximum of 18 *r* reaching the skin above the thyroid over a period of two weeks which, according to him, is much less than the amount of radiation that reaches the thyroid during the usual fluoroscopic examination of the chest *

Uhlmann, in his report of 1956, stated that he thought it significant that in animals cancer of the thyroid had never been produced with X-rays, however, in 1957, Doniach[22] produced thyroid cancer in seven out of 21 rats, when 1,100 rads of X-ray therapy was administered to the rat thyroid followed by prolonged methylthiouracil therapy In only one of 13 animals with this same X-ray dose but without methylthiouracil, did thyroid cancer develop

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*A measure of fluoroscopic radiation was made by the X-ray Department of the Stanford University Medical School The maximum dose of radiation at table-top was 3 2 r per minute A skillful fluoroscopist can cone down the field of exposure to a very small area in the chest thus avoiding the thyroid therefore members of the Department feel that in a well-planned fluoroscopy it would be extremely unusual to expose the thyroid to a greater amount of radiation than might be applied to the same area during therapeutic use for benign conditions

Uhlmann feels that, statistically, the correlation of irradiation and the development of carcinoma of the thyroid is untenable In addition to his own cases, he refers to other reports of 68 children with cancer of the thyroid (Dailey and Lindsay, 23,[23] Horn and Ravdin, 22,[14] and Warren and associates, 23[15]) and only one had had previous X-ray therapy

There is, on the other hand, certain experimental work referred to by Duffy,[3] which indicates that the administered irradiation is potentiated by endogenous endocrine activity in the development of thyroid cancer Such a mechanism may account for the increased risk after the use of X-rays in the infant or growing child, compared to that in the adult Duffy stated, "Doniach[22] has suggested that a small dose of X-irradiation may act as the initiating factor, and that the subsequent 'normal' growth and development of the thyroid from infancy to puberty may be the promoting factor in the production of the thyroid cancer in childhood The dose of the external X-rays, or other radiation, would not then be as important as the time at which it is administered, since the mature adult thyroid tissue is apparently reasonably resistant to the development of radiation cancer "

DISCUSSION

Bordley,[27] referring to the Johns Hopkins' survey, stated "*1* None of these cases received any of their ray therapy at the Johns Hopkins, which might lead one to believe that in institutions where great care was taken by people specially trained for this work, the instance of needless irradiation of surrounding tissues is greatly reduced, *2* In the cases where X-ray was used on the tonsils and the nasopharynx, it was believed by the investigators that the coning of the X-rays was unnecessarily large, and that the spread of the treated field was very much larger than it should have been, with pretty definite indication that the thyroid became involved in the field, *3* There has been no evidence of any malignant changes related to irradiation with the Beta ray applicator. This is perfectly natural, due to lack of penetration of the Beta rays. To my mind, it is perfectly evident that to X-ray someone because a tongue is enlarged, or because he has a laryngeal polyp, or to remove the tonsils in a child, is a rather unnecessary procedure."

Duffy[24] stated, "Although cause and effect have obviously not been proven, the possibility of radiation being a factor in the cause of thyroid and other cancers in the young is such that radiation for benign conditions in infants and early childhood should be condemned." A similar sentiment was expressed by Simpson and Hempelmann,[5] Klopp,[16] Berman,[16] Copeland,[16] Dennis,[28] and Fetterman.[13] If this be the case, what then should be the position of the otolaryngologist who has prescribed radiation as a therapeutic aid for many years? He cannot ignore the reports of the potential hazards of radiation, nor can he discount experiences such as those of the otolaryngologists of the Johns Hopkins Hospital, who have used nasopharyngeal radiation since 1924, and in whose cases it has been said,[27] there has never occurred cancer of the thyroid. A step toward the solution of this dilemma would be a re-evaluation of the indications. One might ask, "has irradiation been really necessary?" For example, could not the 2,500 cases reported by Uhlmann,[21] irradiated for enlarged tonsils and adenoids, throat infections, recurrent colds and impaired hearing, have been reduced to 250 or even 25? Does one have to resort to radiation (as reported[25]) for chronic cough, coryza, mouth breathing, snoring, nasal voice, anorexia, gagging, vomiting and choking due to postnasal drainage? Is radiation really indispensable in treating conduction deafness of tubal origin?

There is no question that much of the radiation prescribed could be dispensed with. I stated this in a previous paper,[26] and presented as an example of a certain group of patients, the case of a seven-and-a-half-year-old girl whose second adenotonsillectomy was supplemented with X-ray irradiation Her good hearing result (see Fig 1) was thought at the time to be due to the combination of surgery and irradiation, but subsequent controls, as represented in Fig 2, treated by meticulous nasopharyngeal surgery but without irradiation, produced the same good results

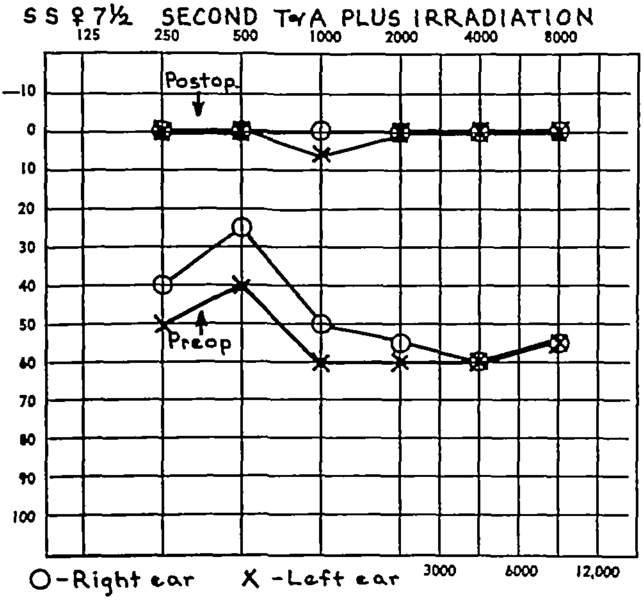


Fig 1 Pre- and postoperative audiograms of S S a 7½-year-old girl The surgery a second adeno-tonsillectomy was supplemented with Roentgen irradiation This was one of a number of cases whose good results were thought at the time to be due to the combination of surgery and irradiation but subsequent controls as represented by Fig 2 suggest that adequate surgery was responsible for the improvement.

Further evidence of unnecessary use of irradiation was pointed out in the case of a 45-year-old male (see Fig 3), who had tubal obstruction with secretory otitis conduction impairment in his only hearing ear He had had one course of 320 *r* of X-ray irradiation to both right and left sides, another course of 700 *r* four years later, and an additional 50 mg radium plaque, Monel-filtered, against each Eustachian tube for a period of eight minutes His recurrent secretory otitis and deafness did not improve Subsequently surgical removal of the nasopharyngeal lymphoid tissue and tonsil tags, nine years after the first irradiation treatment, resulted in a cure of both the secretory otitis media and the conduction deafness Irradiation could have been avoided had surgery been tried first This also demonstrated that masses of lymphoid tissue are not always melted away by irradiation in the doses used for non-malignant conditions

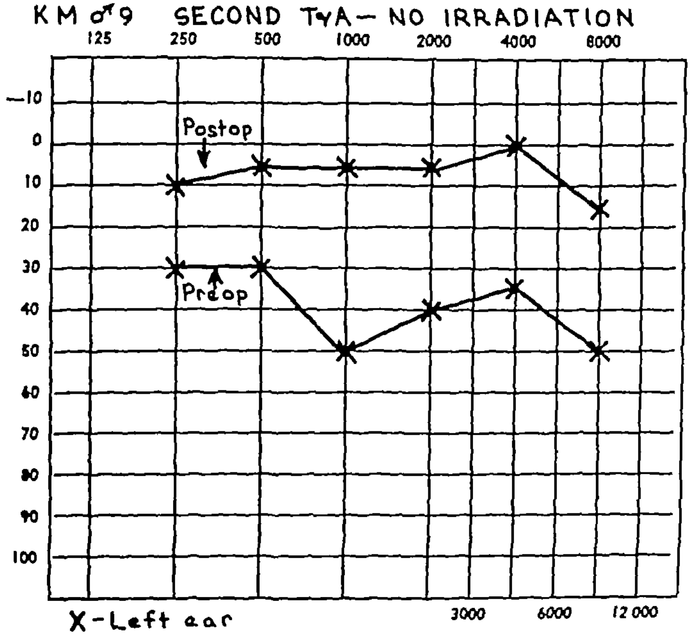


Fig 2 Pre- and postoperative audiograms of K. M. a 9-year-old boy His second adenotonsillectomy without supplementary irradiation resulted in a hearing improvement comparable to the group represented by Fig 1 who had had supplementary irradiation

In general, it can be said that if a patient with a non-malignant ear, nose and throat disease is treated by irradiation only after a fair trial of other adequate therapy, the number of individuals who would be exposed to irradiation would be very small

CONCLUSION

The few cases of cancer of thyroid in children having had prior irradiation, herein presented, in addition to those previously reported, do not permit one to conclude that irradiation of infants and children causes cancer of the thyroid to appear in later years, however, the possibility is sufficiently startling to make one suspicious of potential hazards of even small doses of radiation in children Until the evidence is conclusive, for or against this relationship, one should use great restraint in undertaking irradiation for any nonmalignant condition in infants and children For the otolaryngologist, this caution should prove no handicap, for there are very few benign ear, nose or throat diseases of

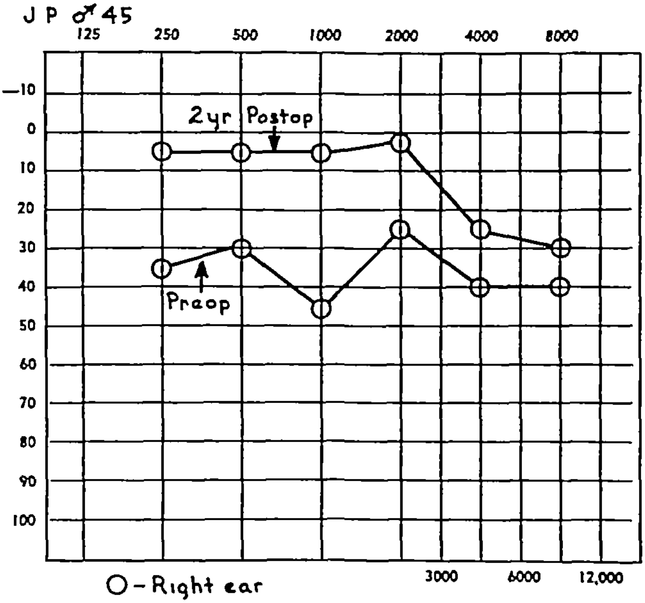
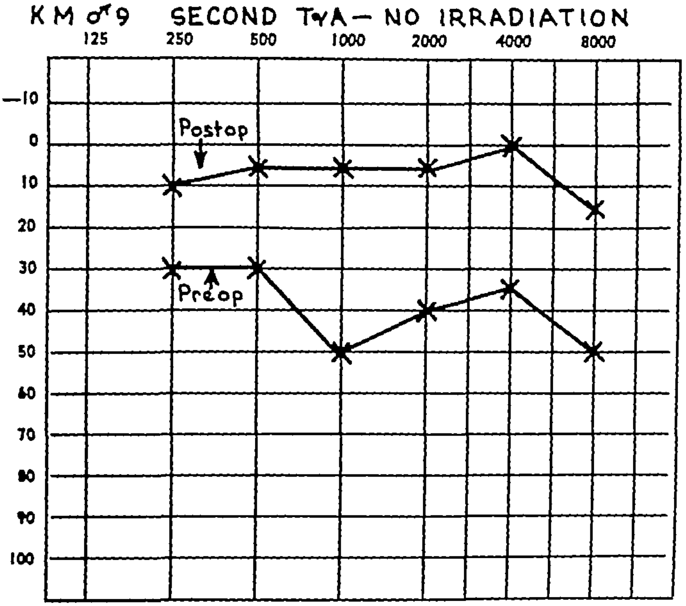


Fig 3 Pre- and postoperative audiograms of Mr J P age 45 Chronic serous otitis media in right ear Course of X-ray irradiation to nasopharynx in May 1947 and October 1951 and one treatment with radium plaque Monel-filtered in December 1951 No improvement until nasopharyngeal lymphoid tissue and tonsil remnants were removed surgically in June 1956

tube for a period of eight minutes His recurrent secretory otitis and deafness did not improve Subsequently surgical removal of the nasopharyngeal lymphoid tissue and tonsil tags, nine years after the first irradiation treatment, resulted in a cure of both the secretory otitis media and the conduction deafness Irradiation could have been avoided had surgery been tried first This also demonstrated that masses of lymphoid tissue are not always melted away by irradiation in the doses used for non-malignant conditions



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infants and children which absolutely require irradiation therapy

SUMMARY

1 Seven cases of thyroid cancer in children are reported, six of them are known to have had therapeutic irradiation in infancy These cases add further weight to the many similar reported cases of childhood thyroid cancer, pointing to X-ray as a major etiologic factor for thyroid cancer in young persons

2 The evidence for the relationship of irradiation and childhood cancer of the thyroid is inconclusive Some series reported show little correlation, however, in the light of reported evidence it appears not improbable that irradiation of the head, neck or mediastinum in infancy may increase the chance of getting thyroid cancer some years later Unless the etiologic connection comes to be disproved, it would appear wise not to use radiation on children if any other therapy can be found

ADDENDUM

Since presenting this subject before the American Laryngological, Rhinological and Otological Society, Inc, at San Francisco on May 21, 1958, an additional case appeared at the Stanford University Hospital, it was called to my attention by Dr Joseph P Kriss, and is being presented through the courtesy of Dr Carleton Mathewson, Jr, who is in charge of the patient

Case 8 R R 9 years of age Irradiation to thymus at three weeks of age Total of 225 *r* were given in a three-week period starting April 18 1949 using 140 kv peak 20 milliamperes filtration ¼ mm copper and 1 mm aluminum half value layer 42 mm of copper target skin distance 50 cm cone field size 10x10 cm but irradiated size 6x10 cm In June 1957 surgery consisting of a left radical neck dissection with the removal of the left lobe and isthmus of the thyroid, was done On *November 4* 1957 additional surgery which involved a right radical neck dissection and the removal of the right lobe of the thyroid was done In January 1958 the child developed dyspnea A chest X ray revealed diffuse bilateral pulmonary metastases Additional therapy in the *form of* I^{131} was given in June, 1958

Interval between irradiation and diagnosis of cancer eight years

Average interval between irradiation and diagnosis of thyroid cancer for all cases herein reported 9 8 years

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516 Sutter Street

ALUMNI ASSOCIATION OF THE NEW YORK EYE AND EAR INFIRMARY

The Annual Spring Meeting of the Alumni Association of the New York Eye and Ear Infirmary last April was so well received that it has been decided to expand next year's meeting, which will take place from April 20-23, 1959

Symposia and lectures on Hearing Rehabilitation, Endoscopy, and Ear Surgery will be conducted It is also planned to offer refresher courses in Mastoid and Fenestration Surgery and Stapes Mobilization Techniques

More complete information regarding the meeting will appear in a later issue of THE LARYNGOSCOPE

CYTOLOGIC DIAGNOSIS AND PROGNOSIS IN CARCINOMA OF THE MOUTH, PHARYNX AND NASOPHARYNX

EUGENE S HOPP, M D ,[*][†]

San Francisco, Calif

According to a survey reported in the *Cancer Bulletin*,[1] mouth and lip cancer comprise 10 per cent of all male cancer This same publication estimates that as high as 80 per cent of deaths from cancer of the mouth could be prevented by early recognition and prompt adequate treatment

No attempt will be made in this paper to discuss clinical findings or treatment in cancer of the mouth and nasopharynx The sole purpose of this study is to describe a valuable adjunct to the early diagnosis of cancer of these areas, and to demonstrate a means of evaluating radiation treated lesions in which repeated biopsies would prove harmful

It was in 1949 that the late Dr Morrison,[2] Dr Wu and I first published the results of the application of the Papanicolaou-Traut[3] smear technique of cytologic diagnosis to cancer of the upper respiratory tract. In that first publication we were primarily concerned with the application of the smear technique to the early diagnosis of lesions in the nasopharynx. The success achieved in this area soon led to the application of the same technique to the early diagnosis of lesions in the mouth, pharynx and even larynx. The results of the cytological studies made in these areas have been excellent. It should again be emphasized, as it was in the original paper, that this procedure is not intended to replace tissue biopsy and histological examination

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[*] Read at the meeting of the Western Section American Laryngological Rhinological and Otological Society Inc., Beverly Hills Calif Jan. 18 1958

[†] From the Sub-Department of Otorhinolaryngology University of California School of Medicine San Francisco Calif

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the cell and degree of cornification, the staining color is not specific As might be expected, greater numbers of cornified cells appear in the tongue and gingival smears, fewer in cheek and post-tonsillar smears

Fifty normal smears from adults of almost equal sex distribution and varying ages show no variation of cytology for sex, age or phase of the menstrual cycle Such studies were reported by Miller et al[6] and Montgomery[5] in 1951

In the normal smear much nuclear variation is encountered both as to size and shape and position in the cell, but the chromatin content is usually evenly distributed and the cell cytoplasm has a distinct, clearly defined border The larger cells in mouth smears range from about 70 to 100 mμ in size and the medium-sized cells range from about 35 to 40 mμ The nucleus is small compared to the size of the cell, being about 10 mμ in the large cells and 5 mμ in the medium-sized cells

Pre-Malignant Cytology Smears in ten cases of leukoplakia of the mouth were examined As noted by Weinman[9] and Montgomery and von Hamm[10] there appears to be no characteristic cell type

Malignant Cytology Mouth smears from malignant areas are usually rich in cells, the cell nucleus and nucleolus are enlarged, multiple nucleoli are frequent, and the diagnosis of malignancy may be made on the basis of thickened nuclear membranes, hyperchromasia, abnormal clumping of chromatin material and uneven distribution of chromatin bits The cell itself has ill-defined borders, may be distorted or even without a visible, true wall Clumps of these cells are characteristic, but they may be found singly Of course, the normal cytology of squamous cells, leukocytes and clasmatocytes, is also found in the malignant smear

Post-Radiation Cytology In carcinoma of the mouth and nasopharynx which is under treatment with X-ray, malignant cells usually disappear or show senile changes after about the third or fourth week of therapy There is an increase in polymorphonuclear leukocytes and in pink or red staining

Technique Various methods have been described for taking smears in the mouth and nasopharynx Gladstone[3] used both gelfoam and cellulose sponges The sponge was rubbed over the surface of the lesion and then sectioned Thirteen mouth lesions were thus smeared Two of these had a positive tissue biopsy for carcinoma and these two also had positive smears The remainder were all negative Montgomery[5] scraped the mucosa with a Woodson's No 2 metal plastic instrument, and Miller[6] and his co-workers used a wooden spatula Both obtained good smears, however, our original technique, slightly modified, still seems the simplest A tightly wound cotton applicator is rubbed over the surface of the lesion and the adjacent area The rubbing must be firm but not sufficient to produce active bleeding The cotton applicator is then rubbed on the surface of a clean, dry glass slide The slide is immediately immersed in the standard fixative solution of equal parts of 95 per cent alcohol and ethyl ether The slide is kept in the solution until ready to be stained Slides may be left in the fixing solution indefinitely or stained after a minimum of one-half hour

The staining technique follows the modified method of Papanicolaou and Traut[7] with but one exception EA 50 has been used to replace EA 36 or 25 of step No 6 More recently the technique of Pharr, Wood and Traut[8] has been followed in the staining procedure

Normal Cytology A study of the normal cytology of the respective areas being smeared is essential to the diagnosis of the malignant smear In general, the histological characteristics of the area determine the cells found in the normal smear In the nasopharyngeal smear there may be found ciliated columnar cells, columnar cells which have lost their cilia, lymphocytes and polymorphonuclear leukocytes Occasionally and particularly in infection histiocytes, epithelial cells, bacteria and erythrocytes are seen

In the mouth and pharynx ciliated cells are uncommon, and squamous epithelial cells predominate The staining of these cells varies from blue to red to yellow While the determining factors in the color range appear to be age or maturation of

TABLE II

RESULTS OF CYTOLOGICAL STUDIES IN CARCINOMA OF THE MOUTH

	Montgomery[13]	Wahl[11]	Peters[15]	Morrison[3]	Peters[11]	Silverman[12]	Hopp	Totals
Number of Patients	15	41	114	10	194	19	25	418
Positive Smears	13	41	110*	10	186**	18	24	402
Negative Smears	2	0	4	0	8	1	1	16
Positive Biopsies	15	41	114	10	162	18	25	385
Negative Biopsies	0	0	0	0	23	1	0	24

* 8 smears reported suspicious grouped with the positive

**32 smears reported suspicious grouped with the positive squamous cells This is especially noticeable in areas of ciliated epithelium where ciliated cells tend practically to disappear The staining characteristics of the cells are probably due to increased keratinization and decreased production of immature cells, with consequent increase in aged or damaged cells

RESULTS

One-hundred-and-four cases of benign lesions of the nasopharynx, mouth, tonsil, and larynx had Papanicolaou smears made without a false positive for carcinoma Peters[11] in a very recent report smeared 401 cases of leukoplakia, submucous fibrosis, scleroma and other benign conditions in the mouth and obtained three false positive smears for a total error of 0 7 per cent Silverman[12] and his co-workers at the University of California, in a fine study soon to be published, reported no false positive mouth smears in a group of 60 patients

TABLE I

	No of Cases of Carcinoma	Positive Smears	Negative Smears
Nasopharynx	12	11	1
Mouth	25	24	1
Tonsil	14	14	0
Larynx	12	11	1

Table I records the results of the cytological studies in the nasopharynx, mouth, tonsil and larynx

Three cases of carcinoma of the mouth were studied cytologically during and after radiation treatment All smears were negative by the fourth week of therapy One remained negative and the patient showed no evidence of recurrence five years post-radiation The other two (anterior pillar and tonsil) yielded positive smears within two months after therapy and were confirmed by subsequent biopsy Silverman[12] and his co-workers have reported a case which illustrates the point very well Their patient was a 46-year-old male found on examination and biopsy to have a lympho-

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2000 Van Ness Ave

ANNUAL OTOLARYNGOLOGIC ASSEMBLY UNIVERSITY OF ILLINOIS

The University of Illinois College of Medicine Department of Otolaryngology announces its Annual Otolaryngologic Assembly from September 29 through October 5, 1958 The Assembly will consist of an intensive series of lectures and panels concerning advancements in otolaryngology, and evening sessions devoted to surgical anatomy of the head and neck and histopathology of the ear, nose and throat. Interested physicians should write direct to the Department of Otolaryngology, 1853 West Polk Street, Chicago 12, Ill epithelioma of the soft palate The lesion disappeared after X-ray therapy, but a small ulceration developed a few months later The problem was to differentiate between recurrence and post-radiation necrosis Biopsy in the irradiated area could have produced considerable difficulty if the lesion proved benign The initial smear was inconclusive but suspicious Repeat smears yielded a positive for malignancy This was then confirmed by biopsy

In Table II the statistics of several mouth smear studies have been assembled Two cases of carcinoma of the mouth were first discovered on routine smear by Peters[11] One had been thought to have an ulcerative stomatitis and the other an hypertrophy of the posterior pillar In Silverman's[12] series, four cases of mouth lesions were first diagnosed as malignant by cytologic studies

In conclusion, the smear technique is not intended to replace tissue biopsy It is a simple method of diagnosis, however, and can enable one to diagnose malignancy at an earlier stage In addition, radiation treated lesions can be kept under long term observation As Peters[11] so well stated "Repeated biopsies might be difficult, but repeated smears and occasional biopsy are possible and often desirable The reliability of the cytologic interpretation increases with the experience of the interpretor Cytology does not replace histology but supplements it"

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than 150 cases of naso-sino-nasopharyngeal problems, both pre- and post-adenoidectomy, as part of a thorough investigation. This also included X-ray examination of the sinuses, bacteriological and cytological studies of nasal and sinus secretions and allergic tests. Our experiences have revealed that the information obtained by radiography of the nasopharynx is usually more complete and accurate than that obtained by other methods, and can be related to the surgical scope when operation is indicated. In addition, we have noted certain aspects in the radiographic evaluation of the nasopharynx which have not been previously discussed in the literature. We are reporting these data and experiences to emphasize the value of radiographic examination of adenoids.

REVIEW OF LITERATURE

Although the literature contains relatively little concerning the radiological investigation of the nasopharynx, nevertheless the potential value of this subject has been appreciated by a number of authors. The majority of these, as might well be expected, have been radiologists. In 1898, shortly after the clinical value of X-rays became known, Mignon[1] mentioned radiographing the adenoids in his thesis on "Radiology of the Respiratory Tract." In 1904, Scheier[2] reported the demonstration of the epipharynx and enlarged adenoids roentgenographically and the disappearance of the adenoids from the X-ray plate postoperatively. Technical progress, however, had not advanced sufficiently as yet to permit satisfactory results routinely, and little more was written on this subject for the next 20 years. In 1925, Grandy[3] described the soft tissue opacity of the adenoids in the nasopharynx and the narrowing of the airway locally. He also noted the increased airway following adenoidectomy.

Bernfeld[4] in 1927 was the first to stress the importance of the size of the nasopharynx in relation to the problem of obstruction of the airway by adenoids, the difficulty of their complete removal and the frequency of recurrences. He believed that complete resection was more difficult and recurrences of much greater frequency in patients with small epipharyngeal cavities. In 1929, Schuller[5] discussed the gen-

SOFT TISSUE ROENTGENOGRAPHY OF THE NASOPHARYNX FOR ADENOIDS [*][†]

JOSEPH L GOLDMAN, M D ,
and
ARNOLD L BACHMAN, M D ,
New York, N Y

INTRODUCTION

The accurate evaluation of the adenoids is of great importance in the proper management of naso-sino-nasopharyngeal problems so frequently encountered in infants and children Both the otolaryngologist and pediatrician appreciate that the clinical examination to determine the status of the adenoids is often difficult and unsatisfactory in these young patients Posterior rhinoscopy is usually impossible, with the result that digital palpation of the nasopharynx is the clinical method most often employed to estimate the degree of obstruction that exists in the nasopharynx, however, this diagnostic procedure is crude and fraught with serious difficulties It is questionable whether a probing finger can reach the vault of the nasopharynx behind the vomer, or determine the amount or depth of lymphoid tissue while an unwilling patient is crying and struggling Thus, information obtained in this manner is often incomplete and even inaccurate In addition, the psychic trauma which may accompany this manipulation is undesirable

In contrast, we have found that radiographic examination of the nasopharynx is a simple procedure which can be performed satisfactorily and with ease in children of all ages Roentgen ray exposure is minimal, approximately that of a routine chest examination We have used this method in more

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[*] Read at the Sixty-First Annual Meeting of the American Laryngological Rhinological and Otological Society Inc San Francisco Calif May 22 1958

[†] From the Department of Otolaryngology The Mount Sinai Hospital and the Department of Radiology Francis Delafield Hospital

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soft palate often brings this soft tissue density in contact with the soft tissues of the posterior pharyngeal wall, and thus reduces both the airway and the demonstrability of the adenoids We have shown, as have others,[10 13 15 18] that the soft palate is in a mid-position with the nasopharynx open during the simple suspension of respiration Phonation, swallowing and crying elevate the soft palate and diminish the nasopharyngeal airway Inspiration and expiration of air through the nose depresses the soft palate about equally and thereby increase the nasopharyngeal airway Position of the patient, whether supine, lateral recumbent, sitting or standing, plays no major role in elevation or depression of the soft palate, however, there is less elevation of the shoulders and thickening of the cervical soft tissues when the patient's head is held erect and the neck is slightly extended For these reasons our lateral views of the nasopharynx are made with the examinee erect, *1* with respiration suspended, and *2* during nasal inspiration

ROENTGEN ANATOMY

The nasopharynx is that portion of the respiratory airway situated behind the choanae and above the soft palate[5 19] The roof of the nasopharynx is formed by the basisphenoid and basiocciput, the posterior wall by the condyloid portion of the occipital bone and the adjacent anterior arch of the atlas, the floor by the superior surface of the soft palate, and the anterior boundary by the vomer and choanae medially, and the pterygoid plates laterally (see Fig 1) The roof, posterior wall and floor of the space are easily recognized on the radiograph The choanae and vomer, of considerable importance in the evaluation of adenoidal obstruction, cannot be directly identified on the film, however, an accurate estimation of the location of the choanae may be obtained since they are on the same plane as the posterior edge of the vomer The lower edge of this bone begins at the posterior margin of the hard palate (the palate bone) and extends upward and backward to articulate with the rostrum of the sphenoid at the under surface of the base of the skull The plane of the posterior margin of the hard palate can be delineated clearly on the film From this point a line drawn upward and backward to eral subject of bony deformities of the nasopharynx as demonstrated roentgenographically. He described the variations in size and appearance of this airspace, and quoted Testut and Jacob who believed that the infantile nasopharynx was comparatively small with a flat vault, while the adult nasopharynx was larger with a high angular or rounded vault. It was also noted that tumors of the epipharynx, including adenoids, caused more obstruction if the cavity was small and narrow. Moulinard[6, 7] in 1949 also believed that the infant type of nasopharynx was relatively small with an axis parallel to the base of the skull, while the adult epipharynx was larger with a more vertical antero-posterior axis. Other reports[3, 8, 9, 10, 11, 12, 13] similarly indicating the value of the radiographic appearance of enlarged adenoids have appeared sporadically in the literature. Brief descriptions of the method and its merits have been published in standard reference texts.[14, 15]

TECHNIQUE

We have observed that a lateral view of the nasopharynx at a six foot target-film-distance and with factors permitting rapid exposure (1/30 to 1/60 second) to avoid motion blurring is most satisfactory. A non-Bucky technique is preferred, since the gradations on the film are more gradual, the contrasts less and the soft tissues are shown more completely. We have used tomographic techniques in the profile view of the nasopharynx, as have others,[16] but have found that this procedure does not yield additional information. Lipiodal studies[17] have not proved of value.

Radiographic visualization of the adenoids results from the contrast between the water-density of the adenoidal soft tissue mass and the radiolucency of the surrounding nasopharyngeal airway. It is, therefore, apparent that the larger the nasopharyngeal airway, the more likely are margins of the adenoids to be demonstrated, even if enlarged. The anterior, superior and posterior walls of the nasopharynx are bony and immobile. The floor of the nasopharynx is the superior surface of the soft palate and mobile. Depression of the soft palate increases the nasopharyngeal airspace and improves the visibility of the adenoids. Elevation of the an angle of about 30° with the horizontal as it extends towards its junction with the posterior wall of the nasopharynx It is thus apparent that the largest nasopharyngeal airway is usually the anterior region just behind the choanae

The significance of the anatomical arrangement just described is further emphasized by the effects of the action of the soft palate The size of the posterior part of the epipharynx can be increased by the depression of the soft palate which occurs during inspiration or expiration The movement of the soft palate, however, is least at its attachment to the hard palate just behind the choanae As a result, the available airway just behind the choanae is least affected by the soft palate motion Because of the lack of soft palate motion in this plane, the high vault of the nasopharynx anteriorly can be considered a compensatory arrangement to furnish the largest possible nasopharyngeal airway for respiration

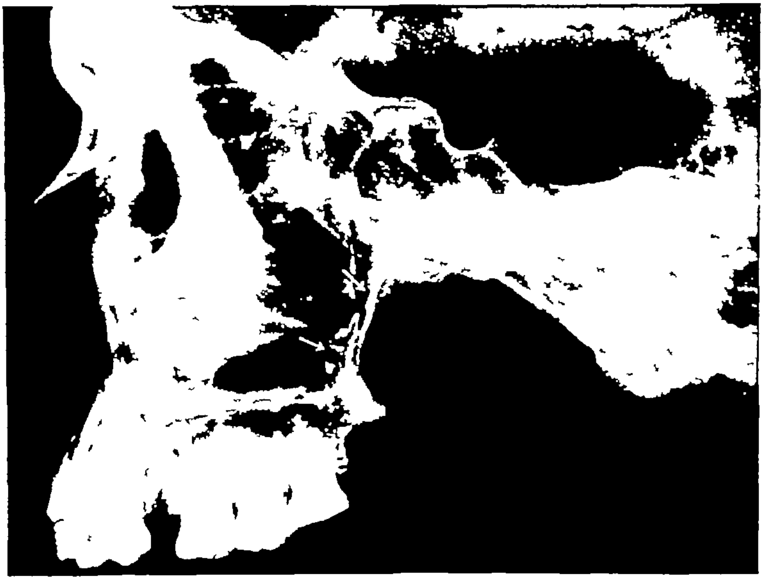


Fig 2 X-ray of dried skull Posterior margin of vomer marked with opaque paste Note close relationship to anterior margin of pterygoid plate and posterior wall of maxillary antrum

the point where the upper anterior margin of the pterygoid plate joins the body of the sphenoid corresponds closely to the posterior edge of the vomer and the position of the choanae (see Fig 2) This line lies very near the posterior margin of the antrum, and the latter also may be utilized as an adequately accurate position of the choanae

The two determinants in nasopharyngeal obstruction are the degree of adenoidal enlargement and the size and shape of the nasopharyngeal space We believe that the importance of the latter has not been sufficiently recognized Both the size and shape of the nasopharyngeal space vary considerably The major factor in this variation is the shape of the roof or fornix of this cavity Usually, the roof is highest anteriorly, just behind the choanae, where the vomer joins with the inferior surface of the body of the sphenoid bone (see Fig 2) From this point the fornix slopes downward and backward at

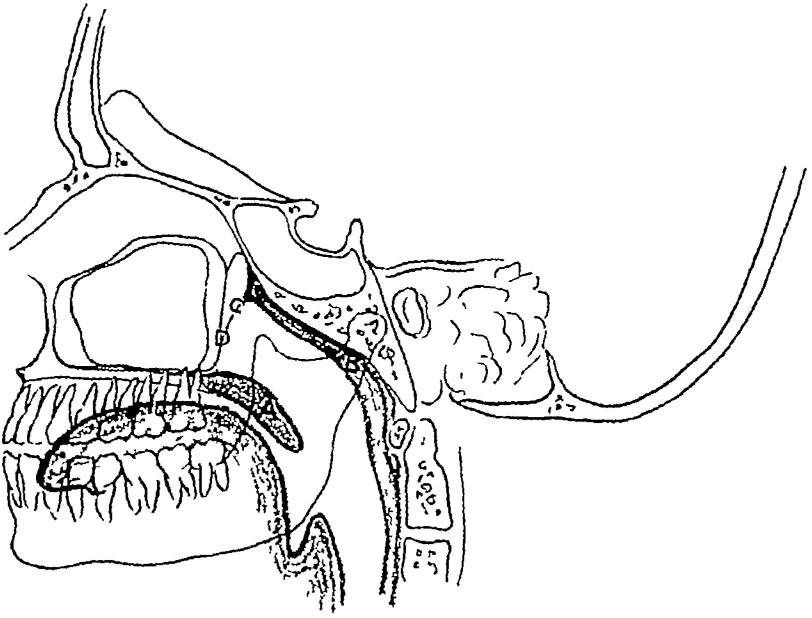


Fig 1 Diagram of anatomy of nasopharynx Nasopharynx located between soft palate (A) and mucous membrane of roof (B) The line of the posterior edge of the vomer is approximated by either the anterior edge of the pterygoid plate (C) or the posterior wall of the maxillary antrum (D)

paratively small nasopharyngeal airways, while in other instances even larger adenoids did not completely occlude comparatively larger nasopharyngeal spaces

ROENTGEN EXAMINATION OF ADENOIDS

The mucous membrane lining the roof and adjacent posterior wall of the pharynx is cast in folds and diffusely infiltrated with lymphoid tissue throughout its submucosa In areas the lymphoid tissue is relatively more abundant, and forms conglomerate nodular masses with crypt-like invaginations of the surface epithelium These are the pharyngeal tonsils or adenoids When infection occurs, there is swelling and enlargement of the diffusely dispersed lymphoid tissue and the nodular lymphoid masses, which result in thickening of the mucous membrane lining of the nasopharyngeal vault The increased width of the mucous membrane may be essentially flat if the diffusely dispersed lymphoid tissue is predominantly involved, nodular in shape if the coalescent lymphoid masses are mainly affected, or a combination of both types Usually the combined form is encountered with marked adenoidal enlargements Nodular enlargements of lymphoid tissue may occur anywhere in the mucosa of the roof The adenoids develop rapidly after birth, attain their maximum size in early childhood and begin to involute at about 8 to 10 years In most instances regression is nearly complete by 12 to 14 years of age

Radiographically, the normal mucous membrane lining of the nasopharyngeal roof is seen as a thin band of soft tissue density lying immediately beneath the inferior surface of the body of the sphenoid bone It begins antero-superiorly in the fornix just behind the choanae and extends backward to merge with the mucous membrane lining of the posterior pharyngeal wall The free surface of this mucosal band can be visualized on the roentgenogram, because it borders the air-containing nasopharyngeal cavity (see Fig 4) It measures no more than 6 mm in width in the normal nasopharynx, and runs parallel with the surface of the sphenoid bone which it covers The normal mucous membrane shows no nodularity A well defined, patent, radiolucent nasopharyngeal airway is

Patients have been encountered, however, in whom the arch of the roof anteriorly is comparatively flat rather than high, and the entire epipharyngeal vault is low (see Fig 3) The superio-inferior diameter of the nasopharynx is thus diminished and the entire nasopharyngeal airway decreased This may be partly compensated posteriorly by marked depression of the soft palate, but anteriorly behind the choanae such lowering of the soft palate is not possible The critical plane for nasopharyngeal obstruction is, therefore, to be found anteriorly just behind the choanae in patients with low, poorly arched nasopharyngeal vaults Clinically, the anterior "critical region" of the nasopharynx is the zone most difficult to explore by digital examination Thus, adenoidal tissue in this recess might not be discovered by this diagnostic method

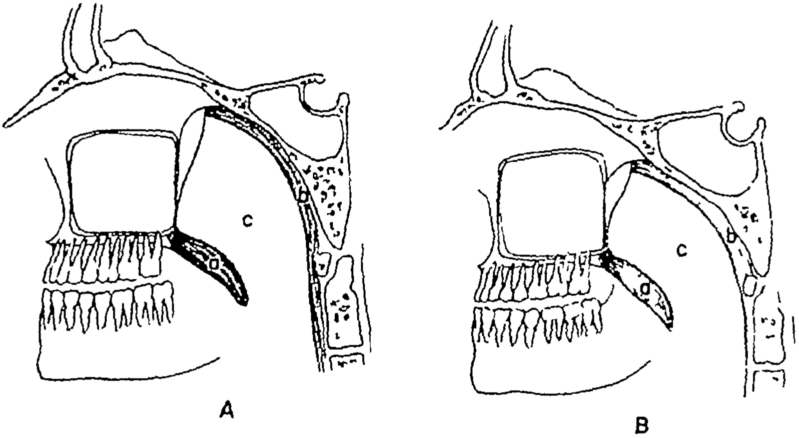


Fig 3 Diagram of nasopharynx with high vault (A) and low vault (B) Soft palate (a) mucous membrane roof of vault (b) nasopharyngeal space (c)

We have observed that usually the nasopharyngeal areas in young children are smaller than in adults, and the vault is lower and less well arched, however, considerable variations in size and height of the vault existed both in the children examined and in the adult radiographs studied for comparison This individual variation plays an important role in the matter of airway obstruction In some patients moderate enlargements of the adenoids caused complete obstruction of com-

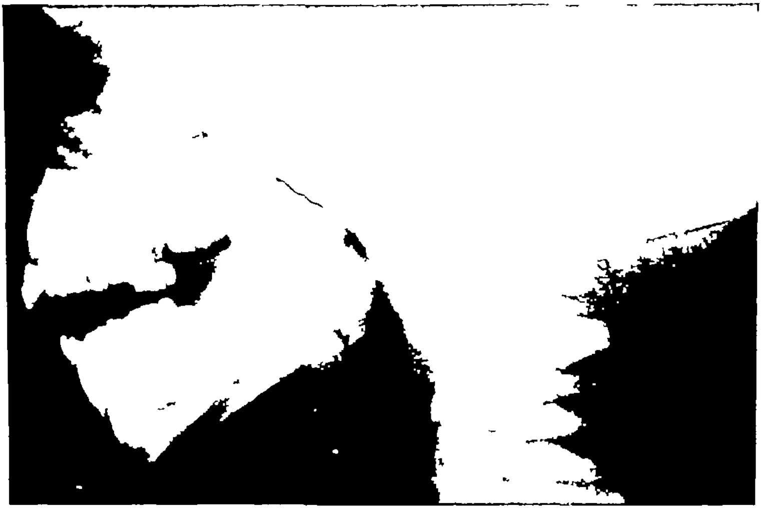


Fig 5-A. Moderately enlarged adenoids Respiration suspended

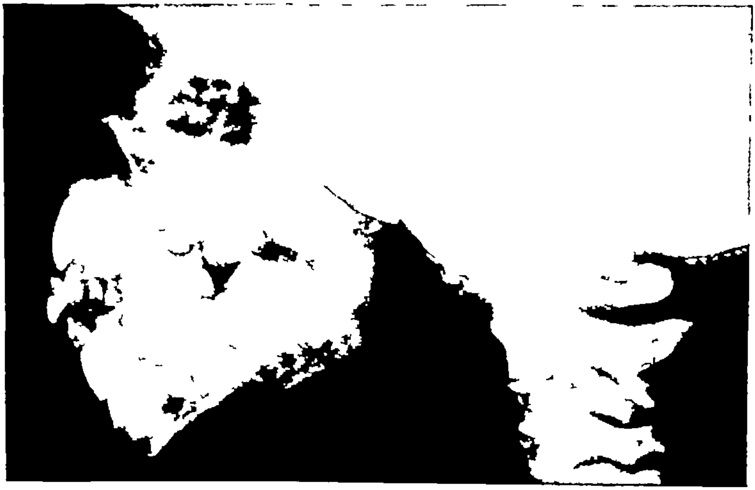


Fig 5-B Moderately enlarged adenoids During nasal inspiration

clearly delineated between the free edge of the mucous membrane of the roof and the superior surface of the soft palate which forms the floor of the nasopharynx

As the adenoids enlarge, the width of the soft tissue band under the sphenoid bone increases, resulting in a corresponding narrowing of the adjacent radiolucent airway In addition to the general increase of width, local areas of greater nodular densities may be seen at the sites of proliferation of conglomerate lymphoid masses which further narrow the airway locally The adenoids are classified as moderately enlarged when the width of the mucosal soft tissue band is greater than 6 mm and there is mild superimposed nodulation, but nasopharyngeal airway is considered adequate (see Figs 5-A—5-B) Marked enlargement is shown by a further increase in width of the soft tissues under the sphenoid bone, usually associated with local crescentic swellings of the mucosa The nasopharyngeal airway is markedly narrowed but not completely occluded (see Figs 6-A—6-B) The final stage of enlargement is characterized by complete obstruction of the airway by greatly widened and nodular mucous mem-

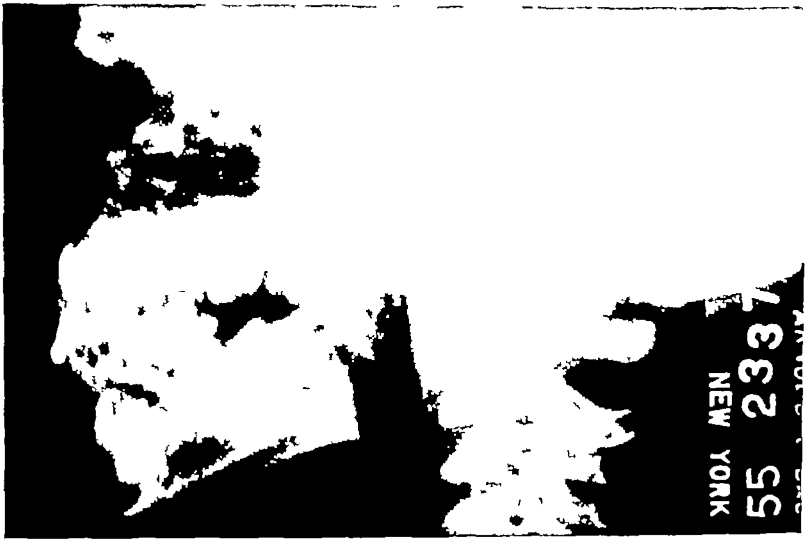


Fig 4 Normal nasopharynx

brane, which extends downward from the sphenoid bone and comes in contact with the superior surface of the soft palate (see Figs 7-A—7-B)

The importance of the mobility of the soft palate floor of the nasopharynx becomes evident in the study of cases of enlarged adenoids In each instance films are made during "respiration suspended" and during "nasal inspiration" When the major adenoidal enlargement is in the posterior part of the roof, the nasopharyngeal airway may appear occluded during suspension of respiration as the adenoids lie in contact with the superior surface of the posterior portion of the soft palate, however, on the "nasal inspiration" film the soft palate is depressed so that a distinct, although narrow airway is demonstrated (see Figs 5-B—6-B), and some nasal respiration is permitted If the adenoids are sufficiently enlarged, the airway is completely blocked at all times (see Fig 7-B) If the major adenoidal enlargement, usually nodular, is situated anteriorly in the nasopharynx just behind the choanae, the degree of obstruction cannot be alleviated by the downward motion of the soft palate since this motion is minimal at this site (see Fig 6-B) For this reason, adenoidal obstructions of the nasopharynx anteriorly are not significantly affected by nasal respiration

Radiographic differential diagnosis of enlarged adenoids is usually not difficult A widened, nodular soft tissue mass attached to the roof of the nasopharynx associated with narrowing of the nasopharyngeal airway almost invariably signifies adenoidal enlargement in young children A common source of error is the shadow of the earlobe projected into the nasopharyngeal airway Uusually, this shadow lies just below and slightly anterior to the external auditory canal (see Fig 8-A), however, if the child's head is not in a true lateral position during the filming, the earlobe may be projected into the anterior portion of the nasopharyngeal airway and cause confusion (see Fig 8-B) Identifying the earlobes in each case should eliminate this problem If doubt still exists, the earlobes may be folded up out of the area and fixed to the temples by adhesive tape prior to the filming[14]

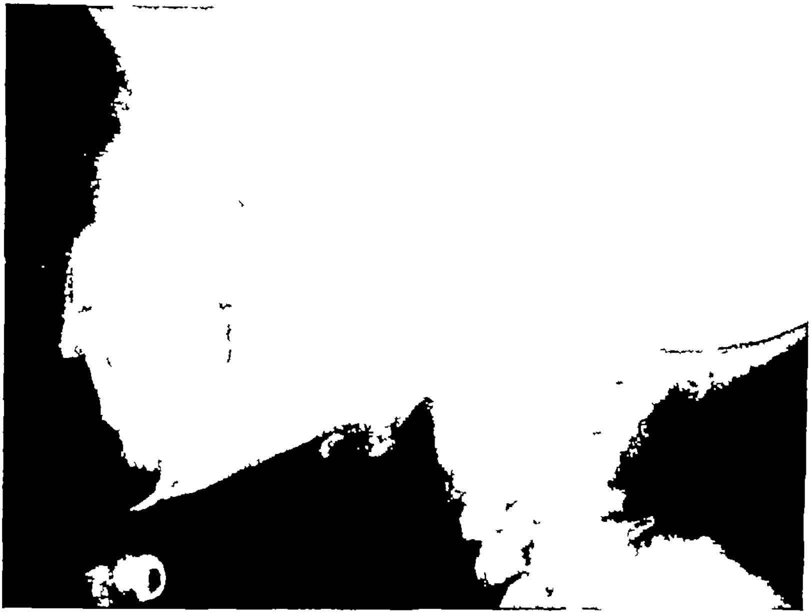


Fig 6-A. Markedly enlarged adenoids Respiration suspended

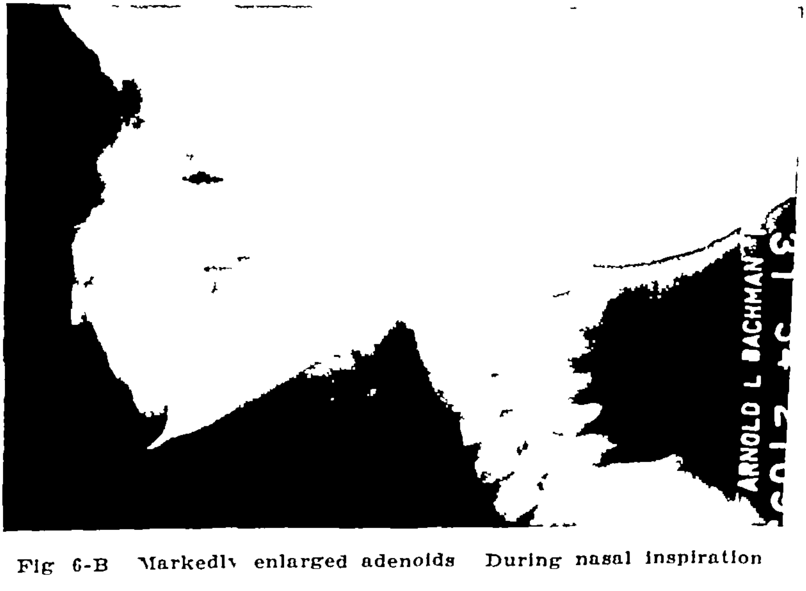


Fig 6-B Markedly enlarged adenoids During nasal inspiration

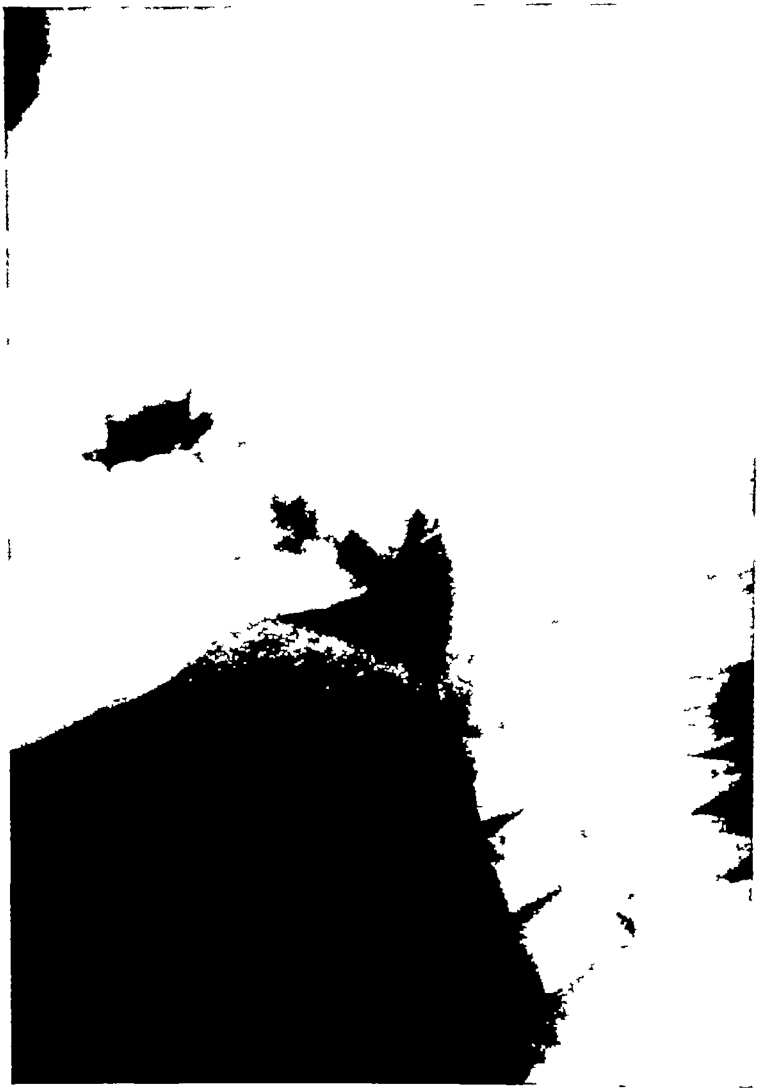


Fig 7-A. Complete obstruction of nasopharynx by greatly enlarged adenoids Respiration suspended.

Choanal and nasopharyngeal polyps, fibromas and malignant neoplasms may be observed as soft tissue masses in the nasopharynx The choanal polyps extend backward from the choanae into the anterior portion of the nasopharynx and do not arise from the vault On radiographs these soft tissue circumscribed densities may be seen separated from the mucous membrane of the vault by a thin band of nasopharyngeal airway (see Fig 9) In addition, the polyps, fibromas and malignant tumors occupying the nasopharynx usually appear after the age when the adenoids have involuted The juvenile and adolescent fibromas as a rule form huge, homogeneously dense, round and sharply circumscribed opacities quite different from the ovoid, lobulated masses seen attached to the vault in the younger children

Radiography of the nasopharynx is a useful method of assessing the success of adenoidectomy procedure Following surgery the entire thickened, lobular soft tissue density observed in the nasopharynx preoperatively is seen to have disappeared The mucosa of the roof is noted as a narrow, smooth band of soft tissue density without nodulation, and the nasopharyngeal airway is wide and patent (see Figs 10-A—10-B) Any areas of residual adenoids are easily identified as local soft tissue nodules projecting into the airway Similarly, recurrent adenoidal enlargement following surgery is apparent as band-like or nodular thickening of the mucous membrane of the vault which projects into the nasopharynx and narrows the airway exactly as do the primary adenoidal enlargements which have not been subjected to operation

In this series of cases, 46 children were evaluated for complaints lasting from several months to two years after tonsillectomy and adenoidectomy In 26 instances enlargement of adenoid tissue, usually high in the vault, could be demonstrated by roentgenography

We have indicated that the anterior area of the vault of the nasopharynx is the "critical region" physiologically This term can be applied also to the surgical considerations of this area Study of the anatomy of the vault of the nasopharynx by roentgenography reveals the reasons for the contentions

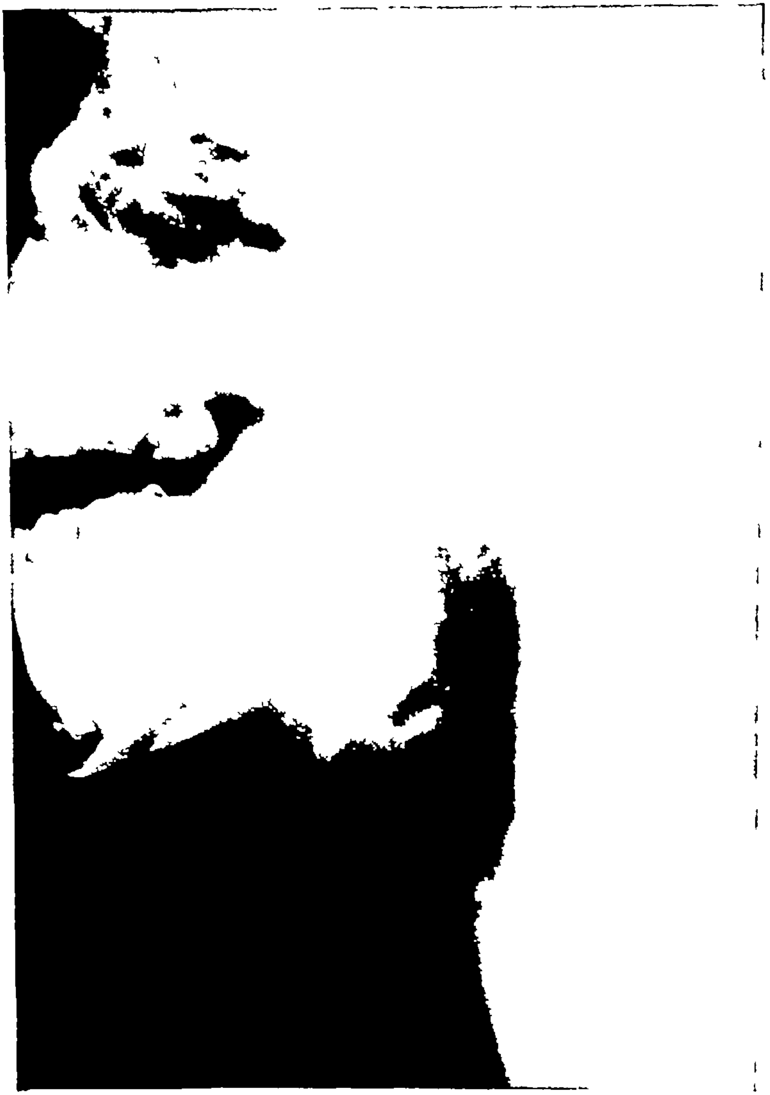


Fig. 8-A. Usual position of earlobe anterior and inferior to external auditory meatus

Fig 7-B Complete obstruction of nasopharynx by greatly enlarged adenoids During nasal inspiration

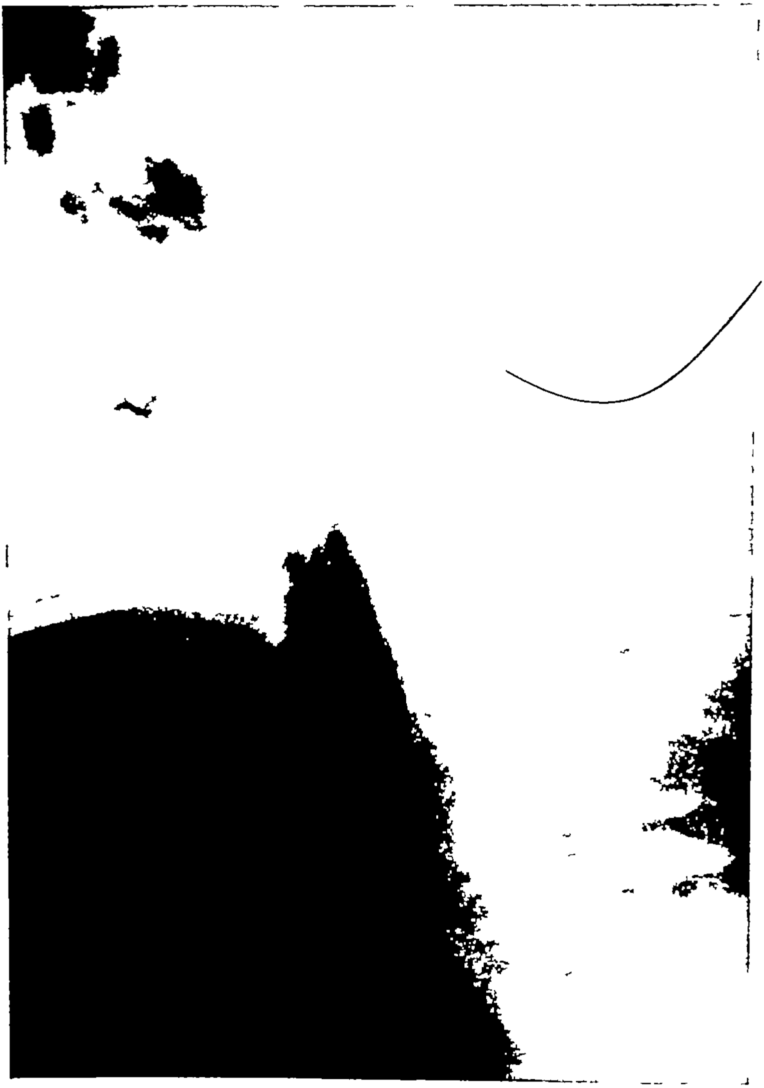


Fig 10-A. Complete obstruction of nasopharynx by adenoids preoperatively

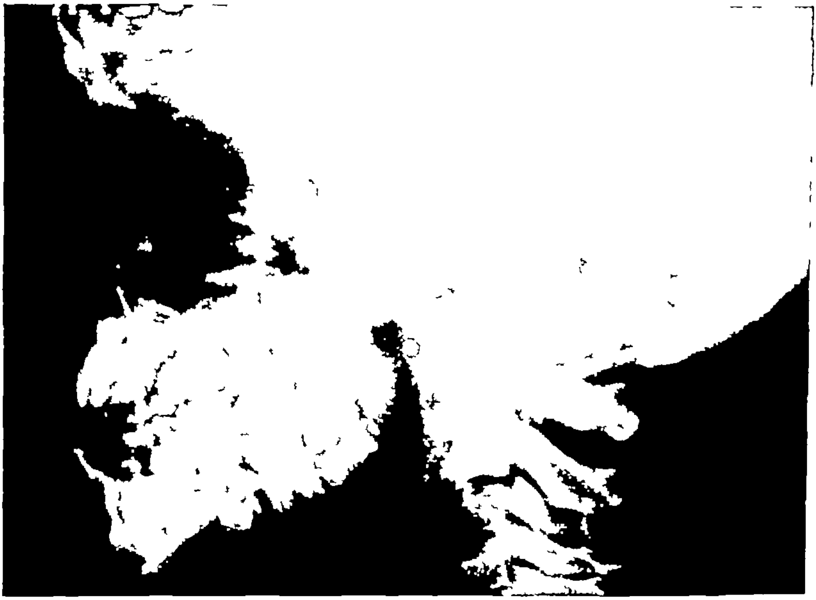


Fig 8-B Earlobe more anteriorly located in nasopharyngeal space due to slight rotation of head

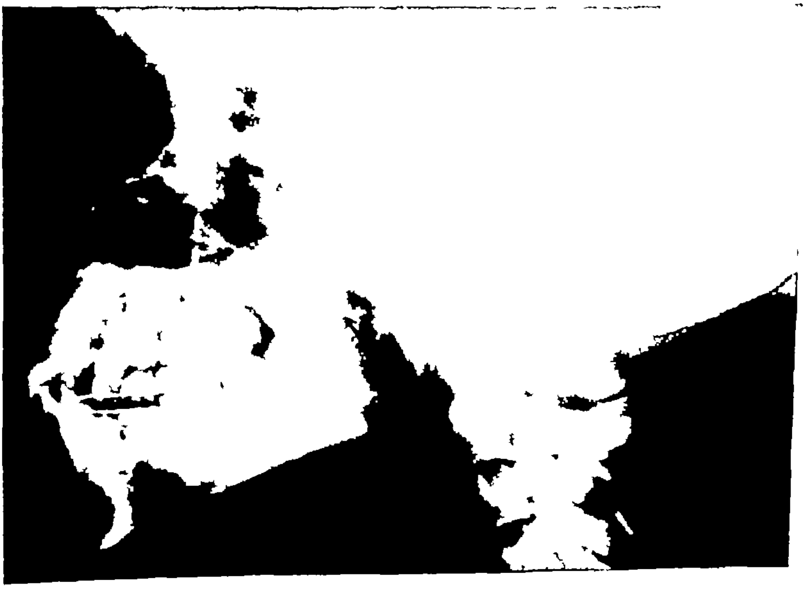


Fig 9 Choanal polyp in nasopharynx

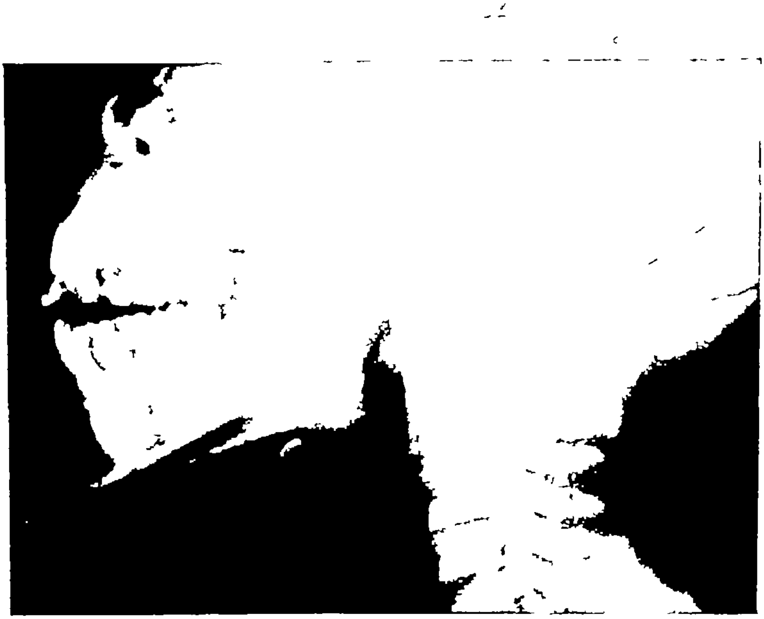


Fig 11-A. Case 2 Enlarged adenoids with respiration suspended prior to third operation

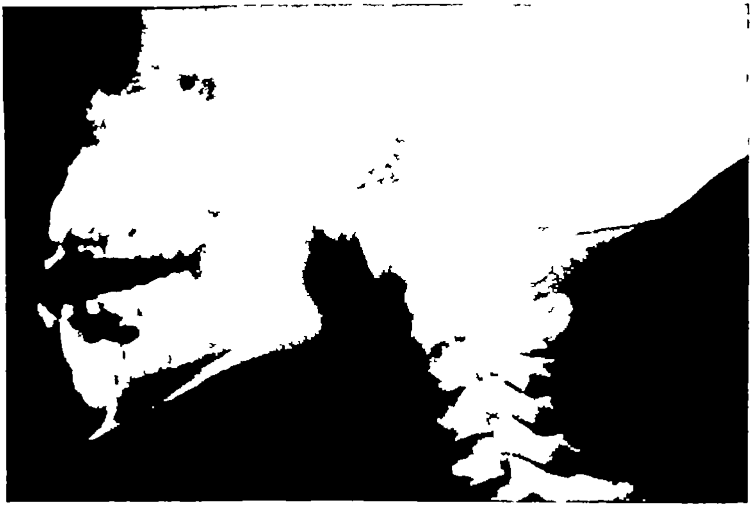


Fig 11-B Case 2 Enlarged adenoids during nasal inspiration

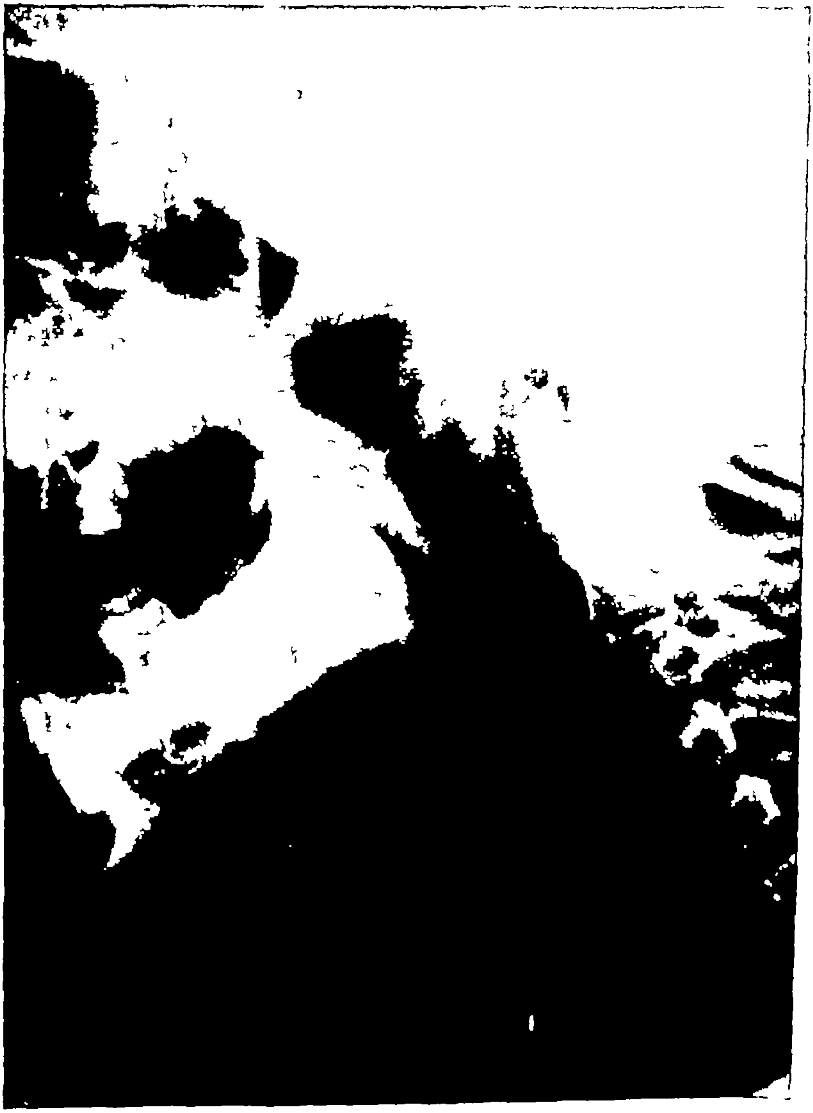


Fig 10-B Clear nasopharynx postoperatively

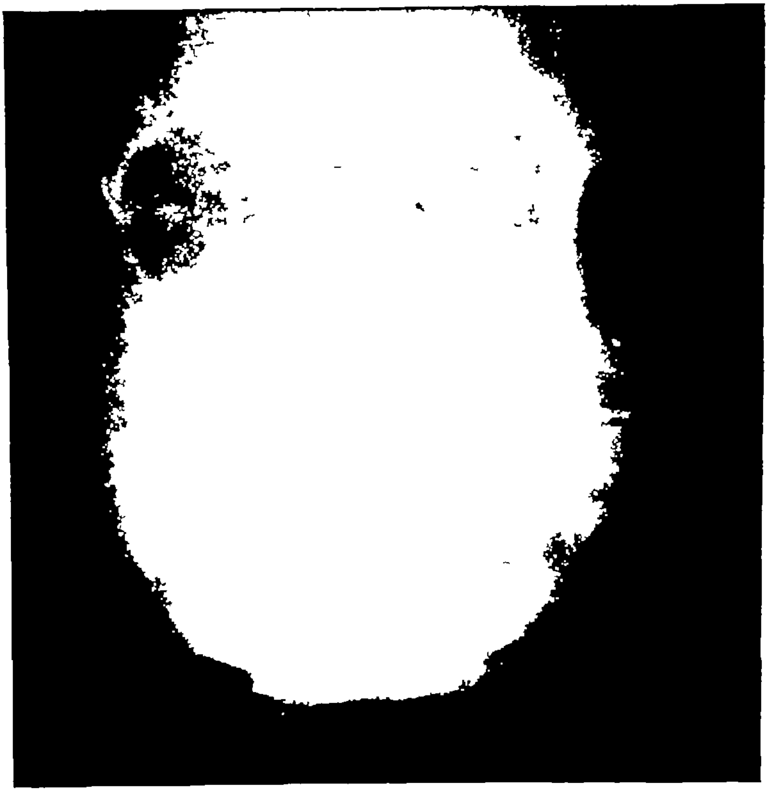


Fig 12-B Case 4 Markedly cloudy maxillary antrums

CLINICAL APPLICATIONS—CASE HISTORIES

The main possibilities in the differential diagnosis of naso-sino-nasopharyngeal problems in children which confront the otolaryngologist include the following condition *1* Adenoidal enlargement with varying obstruction and/or disease, *2* nasal infection and/or sinus infection, *3* vasomotor rhinitis and sinusitis, *4* related ear conditions, *5* occasional polyps and neoplasms For satisfactory solution of these problems, often a complete work-up is required, this must include a detailed history and careful examination, radiographic studies of the nasopharynx and the paranasal sinuses, spreads and cultures of the nasal and sinus secretions, as well as allergic investigations when the latter appear indicated The radio-that complete and direct exposure of the vault of the nasopharynx is necessary to accomplish a thorough adenoidectomy Yankauer[20] has devised a speculum, Love,[21] Baron,[22] Lothrop,[23] Senturia[24] and others have offered palatal elevators for this purpose Meltzer[25] has shown the need of using punch forceps under direct vision to remove remnants of lymphoid tissue in the fossa of Rosenmueller and high in the vault Pedersen[26] suggests the intranasal route for removal of the adenoid tissue in the area we have called the "critical region" of the vault Thus, by demonstrating the anatomy and physiology, roentgenography can be helpful in the planning of the surgical approach of a complete adenoidectomy, in addition to its diagnostic value

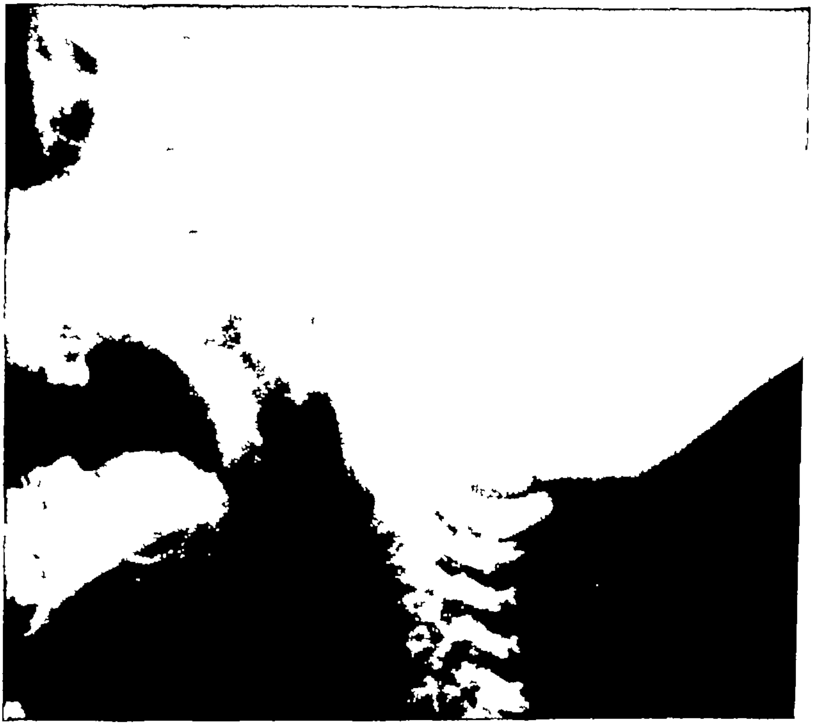
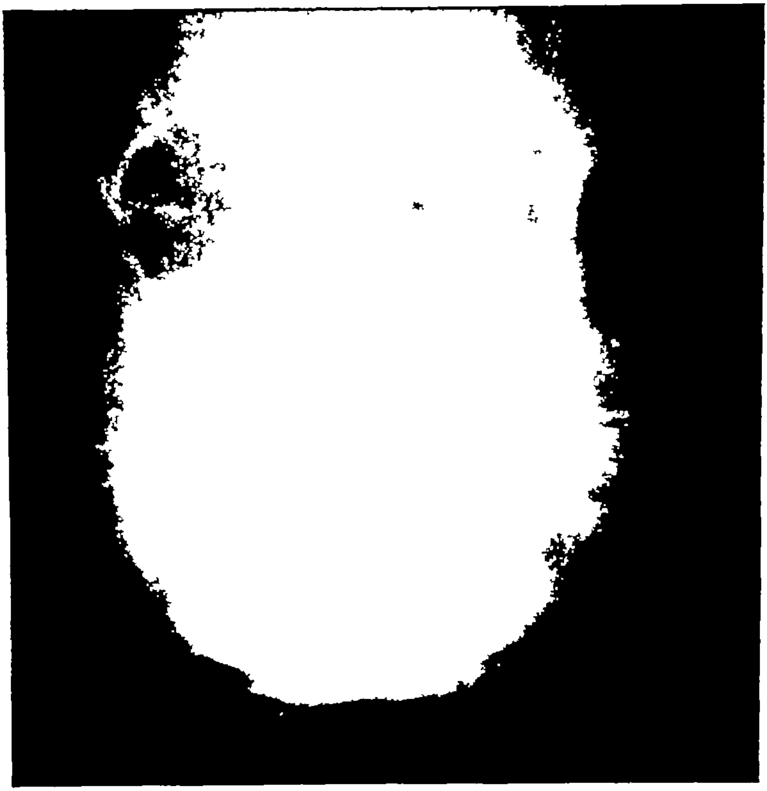


Fig 12-A Case 4 Normal nasopharynx



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PRIMARY ADENOIDAL ENLARGEMENT WITH OBSTRUCTION

Case 1 C W, age 8, complained of constant mouth breathing nasal obstruction and nasal speech Examination revealed no abnormal findings in nose, sinuses or ears, except small amount of secretion in nasal cavities Tonsils were moderately enlarged X rays of nasopharynx showed greatly enlarged lobular adenoids filling the nasopharynx and causing obstruction during "respiration suspended" and almost complete occlusion during "nasal inspiration" Culture of nasal secretions yielded large growths of micrococcus catarrhalis and diphtheroids, a bacteriologic finding often seen in association with active adenoid tissue At operation the enlarged adenoids were removed, following which symptoms disappeared Postoperative X rays of the nasopharynx showed a clear, widely patent airway

POSTOPERATIVE ADENOIDAL ENLARGEMENT, EAR INFECTION, IMPAIRED HEARING

Case 2 C F, age 7, had tonsillectomy and adenoidectomy performed at age of two years For the following five years patient had repeated infections of the ears and upper respiratory tract Hearing became impaired A second adenoidectomy was performed eight months prior to his first visit, but hearing did not improve Examination revealed no evidence of nasal or sinus disease The tympanic membranes were congested and retracted Audiogram indicated a moderate conductive hearing impairment X rays of the nasopharynx showed enlarged adenoids high in the vault (see Figs 11 A—11 B) These enlarged adenoids were removed at a third adenoidectomy Following this operation, the tympanic membranes assumed a normal appearance and the hearing returned to a normal level

IMPAIRED HEARING UNRELATED TO NASOPHARYNGEAL OBSTRUCTION

Case 3 L G, age 8 had impaired hearing A tonsillectomy and adenoidectomy had been performed previously and an evaluation of the hearing loss in relation to adenoidal disease was requested Examination revealed no evidence of nasal or sinus disease Tympanic membranes were normal Radiographic studies of the nasopharynx showed no evidence of adenoids Direct nasopharyngoscopy revealed no lymphoid tissue Audiometric study revealed the hearing impairment to be of the perceptive type

NASAL SYMPTOMS NASAL DISEASE NO ADENOIDAL ENLARGEMENT

Case 4 J B age 3 complained of difficult nasal breathing night snorting recurrent episodes of fever Examination revealed congested turbinates and a moderate amount of thin secretion in both nasal cavities Radiographic investigation showed no adenoidal enlargement in the nasopharynx but marked clouding of the maxillary antrums (see Figs 12-A—12-B) Spreads of the nasal secretions revealed numerous cocci, and cultures yielded large growth of Staphylococcus aureus A Sensitivity tests showed that this staphylococcus was sensitive only to achromycin terramycin and chloromycetin Systemic and local tetracyclin therapy was initiated and the condition cleared rapidly

NASOPHARYNGEAL OBSTRUCTION DUE TO POLYP

Case 5 S T, age 11, complained of difficulty in breathing particularly through the left nostril, mouth breathing and nasal speech An allergic history was elicited Examination revealed a large nasopharyngeal polyp obstructing the left choana. X rays of the nasopharynx demonstrated the polyp arising from the region of the choanae and projecting into the anterior portion of the nasopharynx It was seen to be distinct from slightly enlarged non-obstructive adenoids in the vault (see Fig 9) Breathing difficulties disappeared after removal of the polyp

CONCLUSIONS

Radiographic examination of the nasopharynx is an accurate, simple and safe method for determining the size, shape and position of enlarged adenoids, and the degree of nasopharyngeal obstruction they cause For this reason it is one of the important procedures in the total investigation of naso-sino-nasopharyngeal problems in children Review of the literature suggests that this diagnostic method is utilized less frequently than it deserves It should replace the crude and inadequate method of digital palpation The anatomy of the nasopharynx with emphasis on variations in its size and shape, especially with reference to diagnostic and surgical problems, is presented The radiographic appearance of adenoidal enlargement is described Differential diagnosis is discussed and illustrative case reports are recorded

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A CLINICAL LOOK AT PROGRESS IN EVALUATION OF HEARING FUNCTION *

FREDERICK R GUILFORD, M D ,
and
OLAF HAUG, Ph.D ,
Houston, Tex

INTRODUCTION

Progress in the development of hearing tests has followed a clinical need on the part of the otologist for more information which would contribute to a more complete diagnosis and hence to more adequate therapy Originally he was concerned with the problem of whether or not a hearing loss was present, thus, his early tests were those which measured acuity, or the degree to which a given patient's responses to sound varied from a normal standard The threshold of hearing was later measured as the amount by which sound had to exceed a normal threshold intensity for a given listener to hear The otologist was next concerned, because of the widely differing medical and surgical rehabilitation needs, with the type of hearing loss present This led to the differential diagnostic tests for conductive and nerve type impairments Tests designed to satisfy the above mentioned needs constitute the bulk of audiometric examinations in clinical otological practice today Methods and equipment for the measurement of discrimination ability for speech have been readily available to the clinician for several years, however, it is apparent that he has been slow to grasp the basic clinical importance of these discrimination tests Such discrimination tests and test equipment in the form of turntable and records, which can be used satisfactorily in any office, have been waiting for general clinical acceptance

It is not the intent of this paper to dwell on either the need

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*Read before the Sixty-First Annual Meeting of the American Laryngological Rhinological and Otological Society Inc San Francisco Calif May 22 1958

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for, or the technique of, various hearing tests which have both been abundantly covered in the literature Rather, in reviewing the progress of hearing testing, emphasis will be placed on the development of those audiological tests which we believe to have *basic clinical application*

Adam Politzer,[1] before the turn of this Century, recognized that non-calibrated tests such as the coin click, watch tick, Galton's whistle, whisper and spoken voice, and tuning fork tests "were insufficient as a means for ascertaining the exact condition of the function of hearing in diseases of the ear " It was recognized that these tests produced much variation in results as administered by different clinicians, with different standards It was this variability which the inventors of the modern audiometer sought to eliminate

TESTS OF ACUITY

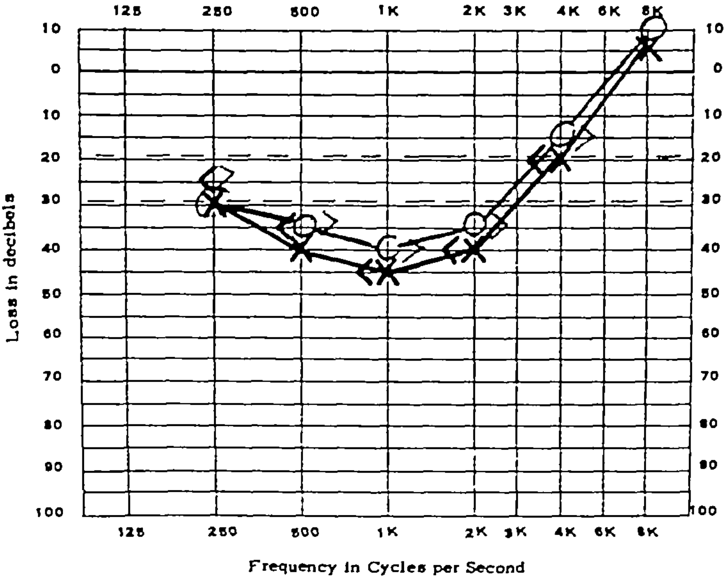
a Tuning Fork Tests

Tuning forks, as they were first used for measuring air conduction acuity, gave some idea of the sensitivity of the ear by measuring how long the patient continued to hear the tone The use of forks representing each octave in the frequencies important for speech hearing, made possible for the first time an approximate plotting of the hearing threshold over a wide frequency spectrum The serious limitation in the use of tuning forks as tests of acuity was the uncertainty as to the intensity of the sound produced

b Pure Tone Audiometric Tests

Pure tone audiometric tests, by air conduction, represented a real advance in the precision of the measurement of hearing loss and the reliability of the results The threshold of hearing was measured as the amount by which sound had to exceed a normal threshold intensity in order for a given patient to hear While this test still serves us as a measurement of acuity for pure tones, or the *degree* of the hearing loss, it is necessary that its limitations be realized Much confusion has resulted until recent years, due to the tendency to interpret the patient's *practical communication handicap* in the light of the air conduction pattern (see Fig 1) The in-

Mrs D. L.
Age 40
4-7-58



History - Like otosclerosis 25 years gradual progress Family history +, ENT history — Paracusis Willisi Hearing aid -good results ENT exam negative - AC like conductive

Fig 1

adequacy of the procedure alone became more apparent with the introduction of bone conduction testing and the development of speech perception tests

c *Speech Reception Threshold*

In the course of investigation of the problem of communication in aircraft during World War II, Hudgins,[2] et al, developed the speech reception threshold tests as a measurement of acuity for speech It was later established that the speech reception threshold usually correlates very closely with the pure tone average of 500, 1000, and 2000 c p s, representing the speech range, and thus it serves as a check on the accuracy of the pure tone findings The speech reception test has been adequately described numerous times in the literature

DIFFERENTIATION OF CONDUCTIVE AND NERVE IMPAIRMENT

a Tuning Fork Tests

Weber, Rinne and Schwabach[3] were pioneers in the use of the tuning fork as an instrument for differential diagnosis of the type of hearing impairment present The well-known tests which they developed made it possible to differentiate conductive impairments from perceptive losses

Politzer[1] wisely predicted the continued importance of the tuning fork as a differential diagnostic instrument in his textbook "We most emphatically state that the tuning fork tests will be of lasting value in the diagnosis of disturbances of hearing"

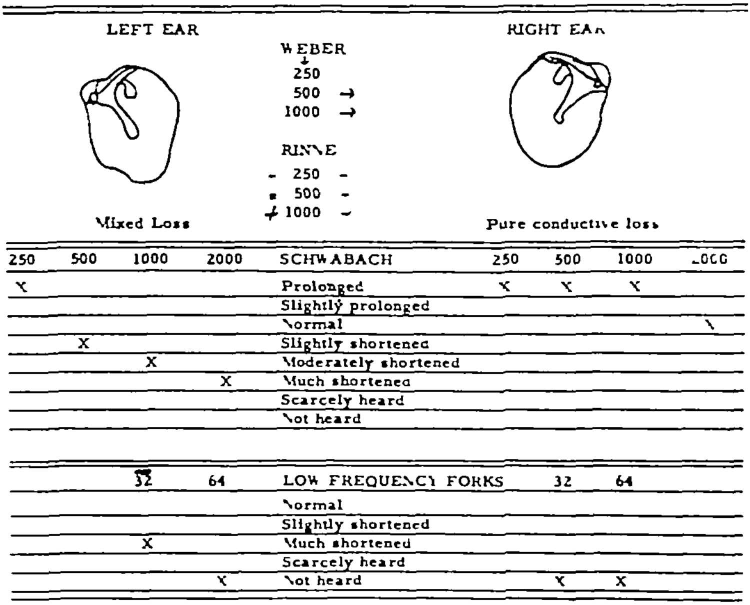
It is interesting to note that all of our clinically applicable pure tone audiometric tests have as their basis the principles established in these early tuning fork tests Tuning forks were further refined in their application and interpretation for making more specific diagnoses of types of hearing impairments or degrees of nerve involvement This proved to be important in the selection of candidates for surgical rehabilitation

I will clarify this particular subject with an illustration from our "Otology Study" sheet (see Fig 2) This affords a graphic method of recording the results of tuning fork tests From the shape and the position of the resultant curves, one can make both a rapid assessment of the patient's hearing status and, equally important, check on the accuracy of the bone conduction audiometric findings

b Bone Conduction Audiometry

Bone conduction audiometry developed as a means of applying the methods of tuning fork testing in a more accurate and controlled fashion With the introduction of the bone conduction oscillator, the intensity of the test tone could be calibrated, regulated and maintained at a constant level In spite of the improvement in the precision in generating the tone, it was soon found, as in the use of the tuning fork, that experience was essential in the application of the tests before any degree of confidence could be placed in the test results It was all too often assumed that bone conduction testing was both easy and routine, however, problems such as placement of the oscillator, confused localization of the test tone, cross-over, and masking, made it a highly individualized and often challenging testing problem It has proven to be the most important *pure tone* audiometric test, now clinically available, for the differential diagnosis of hearing impairment

OTOLOGY STUDY SHEET



LEFT EAR

Mixed Loss

WEBER
↓
250
500 →
1000 →

RINNE
- 250 -
• 500 -
+ 1000 -

RIGHT EAR

Pure conductive loss

250	500	1000	2000	SCHWABACH	250	500	1000	2000
X				Prolonged	X	X	X	
				Slightly prolonged				
				Normal				N
	X			Slightly shortened				
		X		Moderately shortened				
			X	Much shortened				
				Scarcely heard				
				Not heard				

		32	64	LOW FREQUENCY FORKS	32	64		
				Normal				
				Slightly shortened				
		X		Much shortened				
				Scarcely heard				
			X	Not heard	X	X		

Fig 2

c Above Threshold Pure Tone Tests

The recruitment phenomenon was first described in 1924 by Pohlman and Kranz[4] and shortly after by Fowler,[5] in

1928 It was used to differentiate conductive and nerve type impairments, however, so many other tests more clearly demonstrated this diagnosis that they were given slight clinical acceptance

It was only after Dix, Hallpike and Hood[6] demonstrated, in 1948, the usefulness of recruitment testing for the differential diagnosis of end-organ and VIIIth nerve impairments, that recruitment began to receive more general clinical attention

d Speech Discrimination Tests

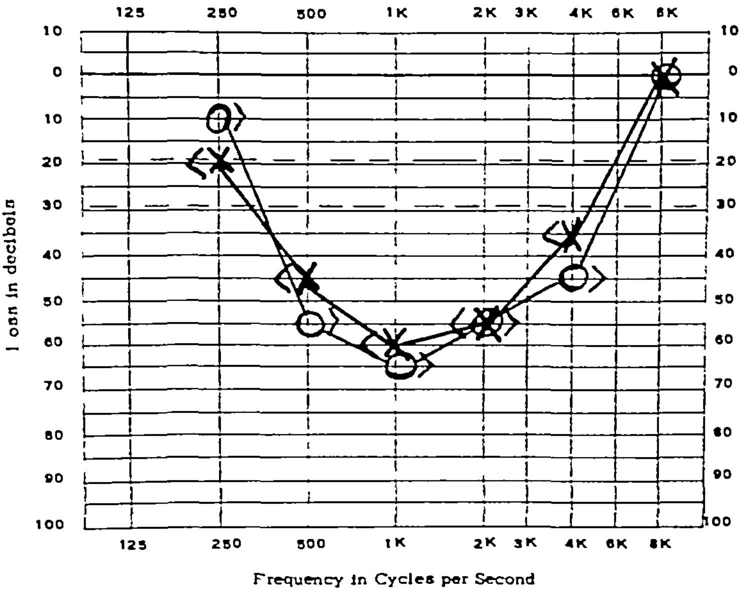
The need for tests other than pure tone for the evaluation of a patient's hearing handicap has long been recognized Oscar Wolfe,[7] in the latter part of the 19th Century said, that in order to make a differential diagnosis, it is absolutely necessary to use the *qualitative* test for speech hearing in addition to the *quantitative test* for hearing MacFarland[8] described a number of early speech hearing tests dating back to 1929

Egan,[9] in 1948, reported the development of various lists of phonetically balanced words to be used in the measurement of speech discrimination or intelligibility of speech This led to the first practical clinical test for assessing the patient's *communication handicap* as distinguished from the more limited evaluation of the quantitative degree of his hearing loss (see Fig 3)

MALINGERING TESTS

Simulated deafness was widely recognized in the latter half of the 19th Century A number of ingenious tests, employing tuning forks and stethoscopes along with careful observation of behavior, were used to diagnose non-organic hearing losses During, and following World War II, the needs of the Armed Services prompted the widespread use and refinement of several audiometric tests for malingering, such as the Stenger, Lombard and Doerfler-Stewart With the current active interest in industrial noise problems, including damage claims, it has become increasingly necessary for the otologist to distinguish the presence and extent of true organic hearing impairments from the non-organic or exaggerated overlay

Mr. J G
Age 38
8-1-55



Limitations of air curve audiometry Pure tone curves same, but wide difference in speech discrimination Aid must be fitted to left ear

Fig 3

TESTING THE VERY YOUNG CHILD

A problem which has demanded increasingly more of the otologist's attention has been the peculiar testing needs associated with the assessment of hearing function in the very young child This has necessitated the development of specialized motivational techniques and equipment for audiometry such as the Dix-Hallpike peep show[10] and the Pediacoumeter[11] (see Fig 4), however, Mykelbust[12] and others[13] have pointed out that observation of behavior is often as important as hearing test results This led to the use of behavioral inventories as an aid in the differential diagnosis of the delayed speech case with poor response to sound

1928 It was used to differentiate conductive and nerve type impairments, however, so many other tests more clearly demonstrated this diagnosis that they were given slight clinical acceptance

It was only after Dix, Hallpike and Hood[6] demonstrated, in 1948, the usefulness of recruitment testing for the differential diagnosis of end-organ and VIIIth nerve impairments, that recruitment began to receive more general clinical attention

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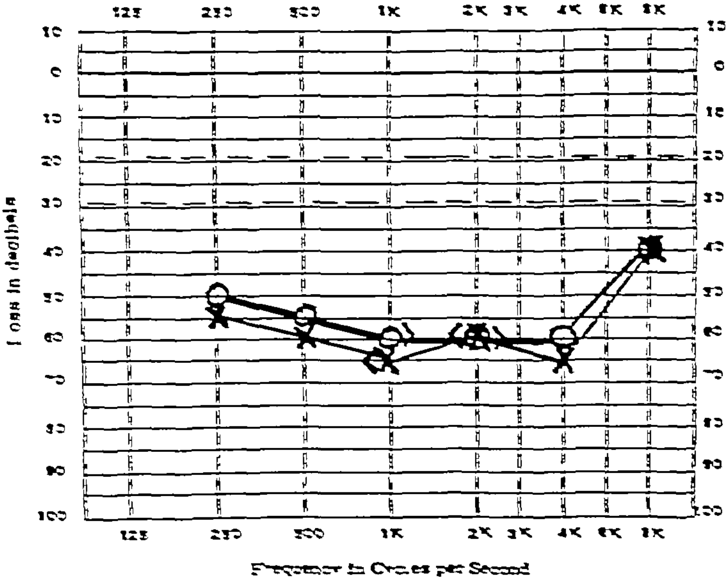
Mrs. J. H.
Age 52
2-12-57



Moderate loss flat curve. Apparently good for amplification but no benefit possible. (See PBM)

Fig. 5.

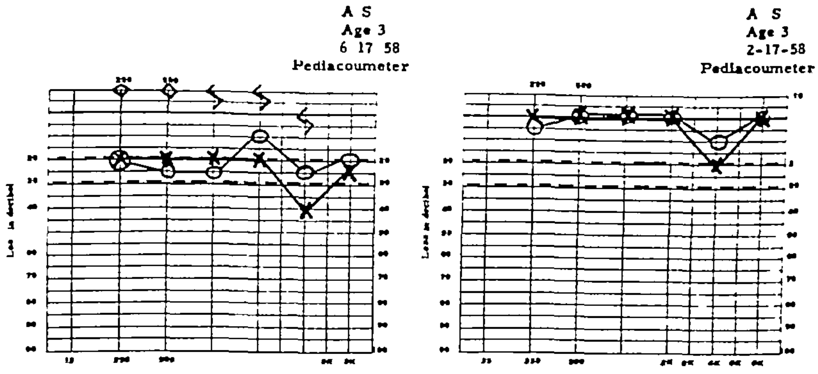
reference. The limitation in the monaural equal loudness test has been that a sloping threshold curve is necessary in order to demonstrate clearly convergence with the most comfortable equal loudness curve.

DISCUSSION

In looking back on this review of clinical progress it becomes necessary to ask ourselves—Where are we presently in the application of appropriate clinical hearing tests for adequate diagnosis? Do we have a practical group of clinical tests which may be economically applied for the accurate diagnosis of hearing problems? In the formulation of such

DIAGNOSIS OF END-ORGAN IMPAIRMENTS

Another problem in otology has been to differentiate the site of neural involvement of hearing impairment, either in the receptor end-organ or in the transmission pathways, in order to provide a more complete diagnosis than was otherwise available For this differential diagnosis, the presence of recruitment has been one of the most valuable indices



Before treatment - Restoration of hearing by medical treatment Illustrates normal threshhold possible on very young children when proper equipment and technique is used

After treatment

Fig 4

EVALUATION FOR AMPLIFICATION

The otologist is now becoming increasingly aware of his responsibility to the patient who is not a candidate for surgical or medical rehabilitation This has accentuated the need for taking various steps to evaluate the patient's requirements and suitability for amplification[14 15] For this evaluation the most useful information audiologically has been that which comes from adequate air and bone audiometry, speech discrimination scores and recruitment testing (see Fig 5)

The two most useful clinical tests for demonstrating recruitment have been the Fowler[5] binaural balance method and the monaural equal loudness method described by Watson[16]

The binaural balance method has been limited in its application in that one non-recruiting ear must be present as a ported tests has led not only to confusion in our specialty, but has also undermined the confidence of the majority of clinicians in their ability to arrive at an accurate clinical diagnosis This has resulted in the widespread practice of either relegating this important clinical function to independent non-medical agencies, or to the rejection of all but the very simplest of air conduction audiometric or tuning fork screening tests, in an effort to evaluate the patient's communication handicap

We firmly believe that the practical value of the routine application of the basic audiological tests mentioned has been adequately demonstrated, but that it needs to be more generally recognized clinically Once the basic group of audiological tests is made thoroughly familiar to the practicing clinician and the resident in *otolaryngology*, as a minimum requirement for the evaluation of hearing function, real progress will be achieved, and we will enter a new era in the assessment of the patient's handicap in communication

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a group of tests, it should be stressed that not all of the old tests should be rejected and not all the new tests should as yet be accepted

Of the tests used clinically, we believe that the tuning fork, air and bone conduction audiometry, speech perception tests, monaural equal loudness and binaural balance tests for recruitment, constitute the minimum battery of audiological tests which should be applied, as indicated, in a routine evaluation of hearing handicap As we have pointed out previously,[17] facilities affording less than this complete hearing evaluation would not serve the situation for providing an accurate diagnosis and a rational plan of therapy On the other hand, more exhaustive, time consuming evaluations with clinically unproven tests cannot be at present justified from a practical point of view The basic audiological tests indicated can be adequately performed by trained personnel with moderately priced, commercially available clinical audiometers having a speech circuit or turntable If the turntable with earphones is used, only a single quiet room is necessary

A number of the newer laboratory tests of hearing function were not included in this discussion, since they have not as yet been established as practical clinical tools We recognize, however, that the development and standardization of these tests in the laboratory have been of vital significance to the clinician

Let us constantly and critically scrutinize the work of the laboratory in the development of new tests of hearing, in order to be prepared to supplant an outmoded test when a more reliable, more practical one appears, however, let us always keep in mind that the purpose of these tests is to provide an accurate diagnosis If that is being adequately done with one or more current clinical tests, why should we feel that additional and often more complex ones are necessary, which at best would only provide confirmatory evidence? We have often allowed research bulletins and special electronic equipment representatives to lead us away from our basic clinical approach to the problem The efforts of some of us to keep up with facilities for performing the very latest re-

ADDENDA

BASIC TECHNIQUES IN MYRINGOPLASTY AND TYMPANOPLASTY

FRED R GUILFORD, M D ,
and
WM K WRIGHT, M D ,
Houston, Tex

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Colby College, Waterville, Maine, presents the Sixth Annual Institute on Industrial Deafness, August 11-20 inclusive Please note that the course has been extended for three days in order to include engineering for noise control Its objective will be to train physicians interested in the problem, nurses, plant engineers and others in initiating and conducting hearing conservation programs in noisy industries The course includes basic otology, audiometry, noise measurement, ear protection and methods of noise control Class is limited to approximately twenty participants

The fee for the course is $250 and includes tuition, room and board The first week will constitute a complete course for doctors and nurses, and the reduced fee for this will be $200 Application should be made to Mr William A Macomber, Colby College, Waterville, Maine

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MALFORMATIONS AND ANATOMICAL VARIATIONS SEEN IN THE MIDDLE EAR DURING THE OPERATION FOR MOBILIZATION OF THE STAPES *

J V D HOUGH, M D ,
Oklahoma City, Okla

INTRODUCTION

The purpose of this thesis is to present some of the variations and abnormalities which may be seen in the middle ear during transaural tympanotomy Mobilization of the stapes is the most frequently performed contemporary operation, using this exposure The conditions here reported and discussed were observed in the course of 500 such procedures

The importance of minutiae increases as the otologist's scope broadens, and his field of operation is seen with greater magnification Numerous procedures[74,130,140,149,169,170] to rebuild, alter, or bypass the conductive mechanism of the middle ear have produced a pressing need for more information regarding the variations seen when the eardrum is lifted and the complex mechanism of the middle ear is viewed Microscopic vision and intense light have revealed structures which have stimulated otologists for decades Now, the operator may engage in micro-orthopedics and plastic revisions of delicate proportions Variations of as little as a fraction of one mm or a few degrees have become more

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this discussion to include those abnormalities of the middle ear which are so often found in association with other anomalies of the external or internal ear or other branchial derivatives

These malformations, limited to the middle ear, are documented here by actual photographs taken at the time of operation In order not to distort the color photographs by labels, sketches of anatomical structures of interest, are mounted beside each photograph, and the structures identified by appropriate pilot lines The photographs were taken through the Zeiss operating microscope, using daylight Kodachrome film The light and the objectives were fixed The F-setting of the camera was 22 The pictures were taken in 1/50th of a second The prints were enlarged in color directly onto a celluloid background

All of the literature available to me, both foreign and domestic, concerning embryology, physiology, anatomy, and malformations of the ear has been reviewed for the past 100 years Local hospital and university libraries and national service organizations have aided in obtaining this literature Photostats and microfilms have been secured of rare and nontransferable articles from such services as the National Library of Medicine, the Armed Forces Medical Library, etc

ORGANIZATION OF MATERIAL PRESENTED

A presentation of the visual experience of these variations and malformations requires some discussion as to the significance of what is seen First, a discussion of fundamental embryology of the area will be given Next, consideration of the individual variations seen in the following structures of the middle ear will be given *1* Muscles and Tendons, *2* Bones and Joints, *3* Nerves, *4* Vessels, and *5* The Round Window Photographs and drawings of ears, demonstrating some of the variations and abnormalities, will then be presented in the same order A brief explanation regarding the purpose of presenting each photograph will be given Comments that seem appropriate will be offered regarding surgical significance, etiology, embryology, and case history important than ever before A slight distortion or the absence of a landmark can be a pitfall for the newly trained surgeon, and sometimes an experienced operator may find his way down an unmarked road into a disastrous result

The report of variations found in the middle ear, or even a segment of it, from the outset is doomed to be incomplete Exhaustive studies of only one small part,[10 14 17 16 18 23 11 13 15 9 35 12 20 19] such as the stapes, have occupied men over long periods of time Study of variations of the ear is, however, important enough to justify the effort from a purely didactive biologic standpoint, but this justification is now reinforced by the currently evident clinical application, furthermore, thoughts regarding the development processes and theories of function may be stimulated in the minds of the readers

In the past the discovery of middle ear anomalies unassociated with other known defects of closely related structures has been extremely rare[5 6] Almost all of the reports in available literature have been of patients with atresia of the external ear with or without other defects of the entire hearing organ[54 110 91 28 34 118 40 77 94 76 111 25 99 95 60 100 71 101,107 53, 103 119 72 104 105 55 57 70 106 96,122 2 22 87 107 108 133 159 114,126 45 123 124 125 79 113 92 154 6 112 21 69 132 68] It is, however, my opinion that isolated *malformations of the middle ear are not nearly* so rare as has been previously thought, indeed, I am sure that many of these have been observed repeatedly although not yet reported A large number of variations and abnormalities have been observed by me in 500 operations, so it seems reasonable to assume that these are not rare The otologic surgeon, therefore, must constantly remember that a normal external canal may be approached and a normal tympanic membrane reflected only to unveil architectural and mechanical problems of several types

SOURCES OF MATERIAL

The reported variations and anomalies listed in this thesis were all found during the course of 500 transaural tympanotomies, most of which were done for the purpose of mobilizing the stapes There will be no attempt to broaden the field of expansion of the head, which tends to separate the primitive external ear from the middle ear. Mesodermal tissue separates the two epithelial layers during the ossicular development. Near the end of the second month of fetal life, the ectoderm thickens at the bottom of the groove and grows toward the middle ear. This solid meatal plate remains closed until the seventh month, at which time it splits and forms a canal. The innermost portion of this plate becomes the superficial layer of the tympanic membrane.

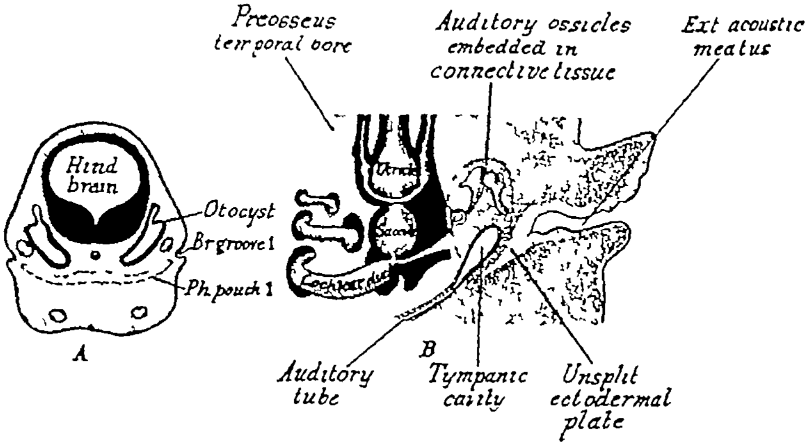
THE MIDDLE EAR

The tympanic cavity and the auditory (Eustachian) tube actually represents a drawn-out first pharyngeal pouch. The second pharyngeal pouch may also be merged with it.[53] The surrounding tissue of the first and second branchial arches constitutes the primordia of most of the other tympanic structures, such as ossicles, muscles, tendons, and connective tissue.

The first pharyngeal entodermal pouch appears late in the third embryonic week (3 mm stage) and expands rapidly. For a time it is in contact with the ectodermal membrane of the external first branchial groove (primitive external canal). This long open tube undergoes a bottleneck constriction near the end of the second month. The constricted portion lengthens and becomes the auditory (Eustachian) tube, whereas the blind outer end of the pouch expands to form the tympanic cavity. At eight weeks (23 mm stage), the tip of the flat tympanic cavity lies alongside the ectodermal tissue of the first branchial groove, which is the future external canal. These two cavities are separated by mesenchyme which later becomes the manubrium of the malleus and the middle fibrous layer of the tympanic membrane. Above, medial and posterior to the area of the future expansion of the tympanic cavity, the other ossicular and muscular elements are being developed from the mesenchymal tissue. As these structures progress to maturity, the unused surrounding mesenchyme disintegrates and the entodermal-lined tympanic cavity expands. This expansion is in pace with the concomitant development of the cartilaginous otic capsule and the external

Finally, general discussion under the headings of, first, etiology, and second, diagnosis, of malformations of the middle ear will be presented

Embryology—(see Fig 1) Drawing from diagram in Arey, "Developmental Anatomy," W B Saunders Co, 1940



Progressive association of the primordia of the external, middle and internal ears illustrated by partly schematic sections *A* At six weeks *B* at three months

FIG 1

THE EXTERNAL EAR

The external ear is formed by a modification of the tissues of the median portion of the first branchial groove and its neighboring first branchial arch (mandibular) above, and the second branchial arch (hyoid) below The auricle is formed by several knoblike structures that appear on the first two arches about the sixth fetal week These are gradually molded together to form the adult auricle

The external auditory canal in reality represents the first branchial groove The membranes (ectodermal) of this groove are for a time (fourth to the fifth embryonic week) in contact with the internal (entodermal) tissues of the first pharyngeal pouch This contact is soon lost, however, by the will be formed At this age the malleus and incus are recognizable, and the incudomalleolar joint begins to separate the two ossicles The incus is beginning to approach, but not touch, the head of the stapes for the formation of the incudostapedial joint Precartilage may be seen in the tissue of the ossicles and the otic capsule

In the eight-week-old embryo (23 mm stage), the stapes is cartilaginous, and its base is pressed hard against the otic capsule The remaining visceral bar connection becomes a strong mesenchymal band This band attaches to the lateral mass of the otic capsule, thus connecting it with the stapes head This will become the stapedius muscle A very small stapedial artery is still present The malleus is still connected to Meckel's cartilage, and the incudomalleolar joint has developed an articulating surface The joining of the long process of the incus with the stapes head has occurred

The embryo, at the age of nine weeks (30 mm stage), has true cartilage forming the stapes and the otic capsule, except in the vestibular region of the capsule against which the stapes rests This area is called the lamina stapedialis This portion of the capsule actually has two cellular zones The more superficial is mesenchyme which lies against the perichondrium of the base of the stapes The deeper layer is fibroblastic and blends with the mesenchyme supporting the epithelial labyrinth Actually this lamina stapedialis fuses with and becomes a structural part of the footplate of the stapes, therefore, it may be said that a part of the otic capsular wall contributes to the formation of the stapes

Between the 12th and the 14th fetal week (50 and 75 mm stage), the crura of the stapes become bowed, and the union of the incus and stapes differentiates into an articulating joint The base of the stapes has now become a part of the lamina stapedialis and blends with the surrounding capsular tissue This blending zone gradually undergoes further change into the annular ligament Actually, an orifice as such never exists, since the stapes is histologically continuous with the marginal cartilaginous vestibular window The annular ligament is first composed of chondrogenic tissue but progressively changes to a fibrous tissue ear canal. As the tympanum expands the lining epithelium surrounds the ossicles and muscles. By the 30th week (270 mm. stage), the cavity formation of the tympanum is complete, but another month is required before the epitympanum is near completion. At term most of the expansion is finished and the cavities are almost mature.

OSSICULAR AND MUSCULAR DEVELOPMENT OF THE MIDDLE EAR

This thesis is so intimately concerned with the ossicular and muscular structures of the middle ear that a more detailed discussion will be made regarding their known developmental processes. A brief chronologic story of embryologic development has been correlated from several authoritative sources.

The stapes is the first ossicle to make its appearance. When the embryo is four-and-a-half weeks old (7 mm. stage) there is a concentration of mesenchymal cells at the cranial end of the second branchial arch, also referred to as the hyoid, or second visceral bar. This is situated lateral to the mesenchyme of the primitive otic capsule, and is separated from it. It is still connected with its branchial arch (Reichert's cartilage, or hyoid bar). When the embryo is six weeks old (12 mm. stage), the stapes is represented by a dense mesenchymal ring penetrated by a large stapedial artery.

At the end of six-and-a-half weeks (14 mm. stage), the stapes is continuous with its branchial arch (Reichert's cartilage) only at the lateral portion, which will become the future head of the ossicle. It is at this age that Meckel's cartilage of the first branchial, or visceral, arch is seen (also called the mandibular arch). This will rapidly differentiate into the malleus, the incus and the tensor tympani muscle.

When the embryo is seven weeks old (17 mm. stage) the stapes is annular in shape like a doughnut. It has moved into close apposition with the lateral wall of the otic capsule. The basal portion of the stapes abuts the otic capsule and produces a concavity in it. The stapes is still connected with its visceral branchial arch (hyoid), and it is from this remaining connection that the stapedius muscle and tendon

THE INNER EAR

The inner ear is produced from epithelium derived from ectoderm Very early in embryonic life (three to four weeks, or the 2 to 4 mm stage) there develops an ectodermal thickening called the auditory placode on the lateral surface of the head This area invaginates to form a deep pit, the orifice of which soon starts constricting and eventually closes This forms a closed sac of trapped ectodermal cells, called the otocyst This becomes separated from the surface of the head and is completely surrounded by mesenchyme At the fifth week (8 mm stage), the otocyst begins differentiation into the vestibular and cochlear portions The cochlea begins to coil at the seventh week (17 mm stage), and the vestibule has developed the primitive utricle, saccule, and semicircular canals The surrounding mesenchyme becomes the otic cartilaginous capsule which begins ossification at about the 17th week of fetal life (125 mm stage) The elaborate embryologic differentiation of this highly specialized structure will not be traced further, as it is not needed for the purpose of this thesis The differentiation has been completed, and the organ is mature at birth

VARIATIONS—MUSCLES AND TENDONS

"Malformations of the muscles of the middle ear, especially their partial or complete lack, have been observed only when associated with other severe malformations"[93] Again, this condition is not so rare as has been previously considered During the course of 500 operations, I have found five patients with a total absence of the stapedius muscle, tendon and pyramidal eminence (see Figs 16, 5, 6, 7, 8) In one patient (see Fig 13), the muscle band was not much more than a condensation of soft tissue

The significance of abnormalities or absence of the stapedius muscle has been the object of highly specialized scientific investigation[160, 117, 90, 163] Apparently the stapedius muscle has the ability to reduce or dampen sound transmission en route from the tympanic membrane to the cochlea Some believe a reflex action may enhance certain sounds as well as

When the embryo is 16 weeks old (112 mm stage), the ossicles are still cartilaginous Ossification then appears first in the incus along the anterior aspect of the long crus

By the 17th week of embryonic life (125 mm stage), bone makes its initial appearance in the body of the malleus It is also at this time that ossification begins in the otic capsule

At about the 19th week of embryonic life (150 mm stage), ossification begins in the stapes by the appearance of a single center on the obturator surface of the base From this center, ossification spreads over the base and along each crus

At about the 28th week of embryonic life (225 mm stage), ossification has occurred throughout most of the ossicles The usual evacuation of the stapes is beginning to occur along the obturator margins This progresses until the crura are reconstructed into channeled troughs, the head is hollowed to form a cylinder, and the base becomes a thinned bilaminar plate This exceptional differentiation is found only in the stapes The malleus and incus, like all of the other bones of the body, progressively become thicker through the development of endochondral bone whereas the stapes becomes thinner, loses bulk and disposes of its marrow tissue Cartilage remains throughout life on all articulating surfaces of the ossicles Cartilage still covers, and will persist, on the vestibular surface of the base of the stapes Cartilage still remains and will persist throughout life in the rim lining of the oval window

By about the 35th week of embryonic life (345 mm stage), the stapes has assumed adult form, as have also the malleus and incus Mucous membrane has lined the spaces of the middle ear and is draped over the tympanic surfaces of the ossicles

At term (367 mm) the adult form of the ossicles is present and their relationships are established The ossicular muscles are fully developed and the mechanism of sound transmission is established for life's sojourn on earth midal eminence during the operation for mobilization of the stapes without bone removal from the external canal wall is quite variable. Although frequently it may be seen in its entirety (see Fig. 2), usually the chorda tympani nerve must be dislocated, and some canal wall bone must be removed before it can be completely inspected (see Fig. 27).

Variations in the length of the stapedius tendon are great. Some are extremely long (see Fig. 31). Some are almost too short to see (see Fig. 4). The unusual projection of the stapedius pyramidal eminence and the extremely short tendon seen in this photograph are extremely rare. The manipulation of the stapes in an operation for mobilization of the stapes can be interfered with by this close proximity. Visualization of the movement of the stapedius tendon is sometimes used to identify certain slight motions of the head of the stapes during mobilization.[130, 140] The size, location, and exposure variations are important in this light.

The attachment of the stapedius tendon is to the neck of the stapes in about three-fourths of ears. Occasionally, it is attached to the head or to the posterior crus (see Figs. 17, 2, 3). Usually the tendon is attached to a spine on the stapes.[24] One writer believed that the spine was the result of a traction process, whereas another felt that the spine was perhaps due to ossification of a certain portion of a tendon.[142] It is my belief that neither is true, since I have observed several cases in which a rather long spine was projecting in a different direction from the line of the tendon, and the tendon was attached to its distal end. If this spine had resulted from either a traction process or a tendon ossification it would have been in line with the tendon.

Discussion of middle ear muscles in this thesis will not include the tensor tympani muscle because it is not usually observed in trans-aural tympanotomy.

BONES AND JOINTS

Variations of the ossicles in an otherwise normal auditory organ are rare.[93, 26] The stapes is probably the most frequently affected ossicle,[93] but the vast majority of reports in the reduce certain intensities[163] Others believe that it is not a muscle of "attention," but a protective adjustor[90] The extent of the true value of the stapedius muscle is certainly not known, but now we can at least be sure that it is not absolutely necessary for serviceable hearing This is proved by an example of the return of hearing in a patient with ankylosis of the stapes and concomitant absence of the stapedius muscle (see Fig 5) After mobilization of the stapes, this patient's hearing returned to a good serviceable level This patient seems to have had no difficulty with tolerance to intense sounds, pitched either high or low and, therefore, does not seem to miss the "protective" mechanism

A case has been previously reported of ossification of the stapedius tendon producing stapes ankylosis[142] This has not been observed in this series, but embryologically one might expect this change rather frequently The stapedius head is joined to the hyoid bar rather late, and this tissue eventually attaches to the otic capsule and becomes the stapedius muscle, tendon and pyramidal eminence, with bone being formed on both ends and around the muscle belly All these structures are derived from the same branchial tissue and one could expect, occasionally, a differential change from muscle to bone

Supernumerary muscles have been reported in the bony facial canal[4 30] This muscle is without insertion and apparently is purposeless Other small muscle fibers have been seen in the substance of the temporal bone, but none has been observed in the middle ear, and none was found in this series

Variations in the direction from the insertion of the stapedius tendon into the stapes anteriorly to its origin in the pyramidal eminence posteriorly are frequently found They are of interest only in that they might hide a certain view of the posterior crus and footplate of the stapes by such a location In the majority, the tendon extends directly posteriorly and approximately parallel to the posterior crus (see Fig 2) In a few instances, it will be directed inferiorly and posteriorly (see Fig 3), and very rarely it will be directed superiorly and posteriorly The visualization of the pyrastapes had almost fallen short of union, and the stapes had turned its head up for a slight distance advantage. Indeed, the union of these two bones, which are embryologically derivatives of separate branchial arches, would make one wonder that much greater variation does not occur. The usual incudostapedial joint is found with the lenticular process of the incus placed slightly more anterior than the head of the stapes. This allows the posterior rim of the head of the stapes to be clearly seen. Frequently the lenticular process is placed squarely on the head and occasionally more posterior than the head of the stapes (see Fig. 2).

The head of the stapes may be extremely hollowed-out or solid, and may be as a rounded knob on a pedestal, or merely a flattened surface on the top of an arch formed by the crura. The normal and the usual is somewhere between these extremes. Bone erosion may produce a variety of knobs, spines, and holes in the head or the neck of the stapes.

The neck of the stapes may be thick or thin, solid or hollow, strong or weak.[24] Its length does not always determine its strength. A long slender neck may well stand a great amount of pressure which might be exerted on it during operative maneuvers.[130,140]

The head of the stapes is usually tilted slightly forward in relationship to the crural arch, however, it frequently meets the arch in a true perpendicular manner, and is occasionally tilted slightly posterior.

The clinical significance of these variations is obvious.[3] If the articulating surface is markedly tilted, efforts to perform a mobilization of the stapes by pressure exerted through the incus will frequently cause distortion and lysis of the joint, whereas recognition that there is a moderate tilt in one of the above directions will allow the surgeon to apply force in a direction that will allow for the tilt. It has been my experience that the two most dangerous positions in this respect are a tilting of the head of the stapes downward or forward. In some instances, mobilization through the incus is impractical. Picks in the head of the stapes are sometimes used to mobilize a fixed footplate. If the incus is placed unusually literature associate ossicular deformities with other severe head and branchial arch deformities In reviewing the literature, many of those reported were found in animals [26,24]

THE STAPES

"In spite of the importance of the stapes, no single element in human anatomy has suffered more chronic neglect This is a strange instance of disregard, since the stapes has great clinical importance in otosclerosis It passes through developmental stages of extreme interest, and is grossly the most captivating bone in the human skeleton For all of its unique fascination as the smallest essential bone and as the most exquisitely fashioned unit, this ossicle has not only been forgotten by investigators in anatomy and otology, but the descriptions of it in standard textbooks of anatomy have become stylized and debased through the years They are inaccurate and fragmentary, commonly perpetrating century-old errors Illustrations are either minute or diagrammatic"[24] Bearing this quotation in mind, an objective description of the unusual anatomy of this bone will be presented, with the discussion of the variations mentioned in the literature and encountered by me in this series

THE HEAD OF THE STAPES

The head of the stapes is normally broad and shallow,[44] and its surface is elliptical and concave for articulating purposes This surface is usually in a near sagittal plane, thus permitting the use of pressure through the incus on the stapes without causing one part to slide on the other, thus producing possible joint separation (see Fig 20) Occasionally, however, the joint will be tilted forward, permitting anterior dislocation if transincus pressure is applied, also occasionally the joint face of the stapes will be facing at a downward angle as though the long process of the incus had overgrown itself, and the joint formation was an afterthought (see Fig 6) Another variation is for the head of the stapes to be tilted superiorly, thus making the articulating surface face more in an upward plane (see Fig 14) This would make one feel that the long process of the incus and the it would be a very exceptional case in which the posterior crus would be straighter and more slender and shorter than the anterior crus (see Fig 5) Actually rare specimens occur in which the anterior crus is longer than the posterior and fairly commonly the crura are equal in length and about alike in curvature (see Fig 31)

Very little reference is made in past literature to a finding which I have frequently encountered These cases are those of crural bowing, either inferiorly or superiorly They may seem to wrap around the curve of the promontory or be curved around the bony facial canal[6] (see Fig 6) Bowing of the stapes crura is probably more frequently seen in a downward direction The intimate bowing around the bony facial canal is extremely rare (see Fig 14) Bowing of the crura must be considered if stress is to be exerted in any direction during an operation

Bony projections may be seen frequently on the surface of the posterior crus A knee-like area may frequently be seen about one-third of the distance down from the head toward the footplate on the posterior crus[24] There is frequently a bony spine on either the head, neck, or high on the posterior crus for the insertion of the stapedius tendon Rarely one may see a heavy bony rod extending from the promontory or the facial canal to join the posterior crus, thus causing fixation to the labyrinthine capsule[1 52] (see Fig 18) I have observed that it is common to see bony bridges which project from the promontory and are very near one of the crura These are seldom fused with it (see Fig 17)

Severe variations of the crura are very rarely seen[23 24] They have been reported only with severe deformities of the skull Most of the severe crural deformities reported in literature were seen in animals[26 24] Isolated human anomalies are extremely rare[26] I believe these malformations are far more common than is realized Fusion of the stapes crura into a double-barreled stapes was observed one time in this series, and has been observed previously[24] This is perhaps due to variation in the primitive stapedial artery or abnormal ossification of the inner crural membrane, or due to a variation far posterior it may be impossible to engage the pick in the head of the stapes without joint dislocation. Often the head and neck of the stapes have been rendered a hollow shell by bony absorption from the obturator surface. The outside appearance may be that of a heavy solid structure, but the application of even a fine pick may break through the shell and cause the head to crumble partially.[74]

One maneuver for mobilization of a fixed stapes depends a great deal on the structure of the head and neck as well as the crura. The pressure in this maneuver is against one area of the anterior portion of the neck or head, and the line of force is in a posterior direction.[130] The head of the stapes is usually tilted slightly forward, and this is an advantage in the application of force in this direction.

THE CRURA

The stapes crura are long arched structures which fuse into one at the neck of the stapes, and are widely divergent as they meet the footplate. They are hollowed on the inside, or obturator surface, making them an inverted rounded trough, the edges of which become more pronounced as they curve to meet the footplate. This trough is usually deeper at the base of the posterior crus than at the base of the anterior crus. This hollowing out is the result of bony absorption and can produce a large number of variations. The crura may be extremely hollowed out to a very weak thin shell; on the other hand, there may be no visible evidence of erosion so that the crura are left very solid and large. This is an infantile type of crura. Bony projections, spurs and eroded-looking pits may frequently be seen, especially on the obturator surface.

The anterior crus is usually straighter and shorter than the posterior. The anterior crus averages 3.62 mm. from the head to the base. The posterior crus averages 3.73 mm. from the head to the base. The anterior crus is the more slender of the two. This description is considered to be almost an invariable one by most authors. There seems to be only one who has disagreed with this description.[75] At least one can say that plane as seen in Fig 14 In this patient there was a severe congenital malformation of the labyrinthine wall, making the area of the stapedius laminalis almost look down on its tympanic aspect This is because the window area is situated under and medial to the facial canal At the other extreme is the footplate that is flat or looking slightly upward, as seen in Fig 31

The bony overhang of the facial nerve above or the promontory below determines the direction and width of the niche in which the stapes must fit The crura are usually attached to the footplate at a slightly superior angulation *in situ*[23] This is an unusual statement since in a large majority of cases the footplate is seen mostly above the crura and behind the long process of the incus and below the overhang of the bony facial canal, thus one would expect the angle of insertion of the crura to be more inferior This is due to the fact that the vestibular window is at an angle of inclination even greater than the angle of the crura, therefore, the crura are attached to the footplate usually at an angle of less than 90 degrees from the superior edge of the footplate to the crura

The trough margins of the obturator surface of the crura extend in varying degrees out on the marginal edges of the footplate These lips may run completely around the footplate to produce a rim or tray edge as in the infantile stapes, or the trough margins may be hardly perceptible on the crura and absent on the footplate In my experience, it is unusual to see this crural trough edge extending onto the margin of the footplate Rarely a small bony ridge is seen on the tympanic surface of the footplate extending between the crura This is called the crista stapedius and is very inconstant It is reported that at times the ridge may be replaced by a crest[23]

THE FOOTPLATE OF THE STAPES

The footplate is usually rounded in an arch on its superior edge, curved with a slight point anteriorly, almost straight on its inferior edge, and gently curved on the posterior edge[24] The footplate may frequently be extremely narrow and long, being wedged into a narrow niche between the facial ridge in bony absorption In Marmozets, the crura of the stapes are often found fused for a short distance below the head[44] In Montremata, which is a true mammal of a low skeletal form, the stapes is normally absolutely columelliform (unicurate stapes)[44]

Figure 15 represents a stapes with only one crus This is the posterior crus with the tympanic side of the base being visible in the photograph The incudostapedial joint has been disarticulated in this ear, and the head of the stapes rotated posteriorly so that the basilar obturator surface of the posterior crus could be seen as it joins the footplate area The crus was fairly well developed, but there was no footplate There is a total absence of the anterior crus, thus making this a completely unicurate stapes This finding was in a patient with unilateral deafness

Complete bony union of the crura may be seen, due to massive otosclerotic mounds filling the obturator space (see Fig 19) In the case of a deep niche, the pathologic bone formation may fill in the niche for the stapes and obscure the landmarks below the stapes neck and upper arch This amount of proliferation is rare In certain anomalies, the crura may be extremely small and fragile (see Fig 14) , in other conditions the stapes may be extremely short and bulky (see Fig 4) In the short bulky stapes the obturator foramen may be very small and the stapes may be almost like a rounded blob of bone (see Fig 4) This type of stapes, obviously, has not developed even to the stage usually seen in later uterine life In late uterine life the stapes is even larger than the adult form and must undergo reduction in size by bone absorption, whereas in this patient the stapes is even smaller than usual, but it has much thickness and, therefore, represents a very early embryologic stage

The crura may join the footplate at a variety of different angles Their junction with the footplate may be at right angles or the crura may be tilted inferiorly or superiorly to the plane of the footplate Usually, the footplate of the stapes is in the vestibular window at an angle slightly off the sagittal plane of the body This may vary to an almost horizontal casionally, the otosclerotic bone is seen in mounds occupying isolated areas, or to a massive degree as mountains filling in the entire niche and covering large portions of the crura (see Fig 19)

THE LONG PROCESS OF THE INCUS

Only the long process of the incus is visible during the ordinary operation for mobilization of the stapes It projects from under the superior canal rim, usually as a long, slender, slightly convex process which bows slightly anteriorly and gradually becomes more medial toward its tip The end of the tip has a structure designed for articulation with the head of the stapes This structure is a small mass of bone which extends medially from the main shaft and bears a flat elliptical disc with a joint surface of cartilage A variety of names have been given to this portion of the long process of the incus, such as the lenticular process, the *os orbiculare* or the Sylvian apophysis[44] Some authorities have considered this a separate bone, but others have held that it is only an epiphysis of the incus[44]

The lenticular process may assume a variety of shapes which are important in present-day surgical procedures in the ear A structure much like the head of the stapes may project medially from the long axis of the process It may rest upon a small but distinct neck and may deviate anteriorly or posteriorly, superiorly or inferiorly, in order to articulate with the stapes The joint surface may be in any of the planes described under the head of the stapes variations, and are important because of the reasons listed there Bony strength of this head and neck are important, due to the possibility of fractures during various operative maneuvers

Often the long process of the incus does not have an articulating head and neck, and there is found only a flat articulating surface on the medial side of the long process of the incus

The lateral side of the long process of the incus may have a variety of bony projections A spine-like structure may be seen on the lateral surface at the very end of the process (see and the promontory It may frequently be generously wide with much of its area being superior to the crural insertion (see Fig 10) Rarely the inferior margin is seen in its completeness (see Fig 31) There may be a slight extension of the footplate, either anterior to the anterior crus or posterior to the posterior crus In one patient, I observed a marked extension posterior to the posterior crus of about 1 mm This shelf was proven to be present on mobilization by visualizing its free margin

The average length of the base of the stapes is 2 99 mm with variations of from 2 64 mm to 3 36 mm The average width is 1 4 mm with variations of from 1 08 mm to 1 66 mm [24]

The annular ligament connects the circumference of the stapes to the rim of the oval window, and is very frequently the site of otosclerotic bony invasion, especially in its anterior area [168,31] Due to the embryologic development of the annular ligament, which is derived from the same tissue that later becomes the bony labyrinth on one side and the footplate of the stapes on the other,[24] it is reasonable to assume that free cartilage or actual cartilaginous nests may devleop and remain within its substance [93 28] These nests might become osteogenic and produce bony deposits capable of causing footplate ankylosis Thin bridges of cartilage in the annular ligament presumably could become ossified in the middle decades of life much as cartilage in other regions of the body undergoes such change

The thickness of the footplate is the most variable of the areas considered An extremely thin, almost transparent, footplate is frequently seen On the other hand, a thick, strong, opaque footplate is common [131] These extremes seem to be normal variations Otosclerotic infiltration may involve a small rim area, or may when advanced, change a portion of the footplate into heavy otosclerotic bone and leave the remainder quite thin and normal The anterior areas are the most commonly infiltrated Smooth infiltration of the entire stapes and annular ligament so as to obliterate all fenestral and footplate identification may be seen (see Fig 22) Oc-rare, but because this area has not come under observation in the past as often as the epitympanum I have encountered one such frozen joint between the incus and stapes in this series

A review of the literature on the histopathology of ossicular articulation and particular discussion of the findings of foreign authors has been done[46] It was found that there were four distinct layers, almost constantly found in all ossicular articulations They are from the bone outward *1* The bony layer, *2* The layer of calcified cartilage blending with bone, *3* A layer of hyaline cartilage, and *4* The terminal or meniscoid articulating surface A very interesting finding has been the lack of disease in the joints, even in a large number of patients who had middle ear suppurative disease It has been considered, however, that actual ankylosis of the incudomalleolar joint is usually the result of inflammation

NERVES

Only the facial nerve and its chorda tympani branch needs to be considered in this thesis Marked variations of the position of the facial nerve in its horizontal course across the middle ear are extremely rare[93] Minor variations are common, and are of great importance in the region of the oval window where present-day instrumentation is common There usually is a definite bulge of the bony facial canal just lateral to and above the footplate of the stapes This bulge is usually not sufficient to hide the superior margin of the footplate Marked inferior and lateral bulging occasionally hides a part of the footplate and crowds the crura against the promontory below Obviously, this will hinder instrumentation, and may predispose to nerve injury if forceful entry to the footplate area is made The facial nerve in its bony covering may present only a very small bulge in the labyrinthine capsule wall, which will represent a nerve of small diameter, or one that is deeply placed in the bone (see Fig 18) The opposite extreme is the huge nerve and bony canal that can be seen in Fig 16 This is an unusually large fallopian ridge

Fig 24) This usually points slightly anteriorly, and gives the appearance of the bow of a ship Frequently, the opposite of this may be seen, in which the process rapidly tapers off at the end as it meets the stapes, giving a rounded-off appearance (see Fig 23) The application of various instruments for transincus pressure on the stapes will depend on the direction, topography and strength of this area Slipping-off or fracturing can result from lack of consideration of these variations

Erosion or necrosis of the lenticular process by disease will be discussed under etiology and with the presentation of the case in Fig 21 I have seen complete erosion of the lenticular process of the incus three times in this series in the presence of a normal eardrum and canal I am sure that it will be seen much more often in the future than in the past This necrosis, if complete, produces a gap in the ossicular chain and results in an air conduction hearing loss of about 60 db

A total separation of the incudostapedial joint without necrosis is reported in this series Discussion and descriptions are treated elsewhere This is the second patient reported in the literature available to me

In this series, variation in direction of the long process of the incus as it projects downward is at least 45 degrees

Bony fusion of the lenticular process of the incus with the head of the stapes and the handle of the malleus is a rare anomaly, and is presented in this series (see Fig 8) As far as I am able to ascertain, this is the first case of such abnormality reported in the literature This was a huge bony mass which involved all three ossicles Such an anomaly requires a triple arthrolysis before a mobile sound-transmitting apparatus can be obtained

A much simpler fusion at the incudostapedial joint may occur unassociated with any other abnormality Numerous reports have been made of simple joint fusion of the incudomalleolar joint, but I have found no reports of incudostapedial joint fusion The reason, I believe, is not because it is more the anomalies reported have been of the descending portion of the facial nerve and not the horizontal portions.

VESSELS

Vascular anomalies of the middle ear are extremely rare but must be constantly kept in mind. Among the anomalies, the so-called persistent stapedial artery is one of the most commonly known.[93, 30] This artery is a persistence of a primitive vessel which is a branch of the internal carotid artery. It perforates the floor of the tympanic cavity and progresses over the promontory, passes between the crura of the stapes and enters the facial canal. It later enters the cranial cavity and divides into branches to the dura.[93, 155] I have not encountered a persistent stapedial artery in this series. Although it has been commonly reported that this could be the cause of some types of tinnitus, I could find no documented reports of human cases in the literature, however, there have been many references to this anomaly in animals.[155]

Another common anomalous artery which should be mentioned, originates from the superficial petrosal branch of the middle meningeal artery. This vessel may accompany the facial nerve and may be found in the mucous membrane along the posterior wall of the niche of the oval window, passing through the crura and branching into a plexus on the promontory. I have not observed this anomaly.

Branches of the vestibular artery may be in close proximity to the labyrinthine surface of the footplate of the stapes. This artery is a branch of the internal auditory artery. Profuse bleeding from the vestibule may occur by accidental tearing of this vessel during mobilization of the footplate. If the vessel were so closely bound down to the footplate as to cause tearing of it during manipulation it would be considered to be in a very rare anatomical position. The cause of profuse bleeding in the example to follow is not known, but it is assumed to be due to the above anatomical variation. During the mobilization of a stapes footplate in one patient of this series, the following sequence of events occurred. Instrumentation was proceeding via the head of the stapes

A bony dehiscence in the facial canal wall is of great importance These are not uncommon in my experience, and invite injury to the facial nerve by either mechanical injury or inflammatory involvement[93] Usually the dehiscences are located just above the oval window[93] and are covered with a layer of connective tissue and mucous membrane[144] They are usually oval in shape and the soft tissue may bulge out of the opening slightly[50] "This is explained by the fact that the facial nerve originally lies in a sulcus of the labyrinthine capsule, which is closed to form a canal by the formation of a bony cover or a connective tissue base in late embryonic life and the first year of the post-embryonic life"[50] Defects of ossification may occur, especially in connection with a hyperplastic condition of the mucous membrane of the middle ear

The chorda tympani may be very large or extremely small in diameter It usually enters the bony external ear canal (Iter chordae posticus) on its edge just lateral to the stapedius tendon Occasionally, the nerve enters its bony canal 1 or 2 mm external or lateral to the external canal edge This was observed in three ears of this series There may be a slight variation in the location of bony entrance on the rim of the canal wall Using the right ear as an example and considering the top of the head to be the 12 o'clock position, the chorda tympani may enter its bony canal between 9 o'clock and 10 o'clock It is usually at a position just superior to the end of the fibrous annulus of the tympanic membrane As the nerve continues superiorly along the canal rim it seems to function also for a short distance as an extension of the fibrous annulus of the tympanic membrane A varying amount of bone covering is found over the nerve along the rim

No extensive hypoplasia or absence of the facial nerve or the chorda tympani was observed in this series, and I have found no reports of malformation involving the nerves alone in the literature available to me A marked hyperplasia of the facial nerve, or its bony covering or both, is reported here in Fig 14 Malformations of the facial nerve may be found in conjunction with other severe anomalies[204] Usually

PRESENTATION OF PHOTOGRAPHS AND DRAWINGS AND DISCUSSION OF ANOMALIES AND VARIATIONS OF THE MIDDLE EAR

when suddenly a profuse hemorrhage occurred from the vestibular window. This occurred as the footplate was seen to become slightly mobile. This hemorrhage was definitely a pulsating type of bleeding, and was so rapid that within a matter of seconds the entire middle ear, the ear canal, and the ear speculum were filled with blood; it was so rapid that the suction could not handle its volume. This bleeding gradually subsided over a period of four to five minutes and eventually stopped entirely, never to recur. Although mobilization attempts were discontinued, and consequently there was little postoperative hearing improvement, the profuse hemorrhage apparently did not damage the labyrinth, since hearing deterioration has not followed.

Two other vascular variations should be mentioned although neither was seen in this series. It has been reported that, rarely, there is an absence or a dehiscence of the floor of the middle ear allowing the jugular bulb to herniate upward into the middle ear; also, vascular tumors, such as glomus jugulare, may arise in this area and should be remembered in diagnostic differentiation.

THE ROUND WINDOW

Variations in the size, location and shape of the round window are interesting and sometimes clinically significant. Otosclerosis can cause complete occlusion of the round window.[89, 142] It has been found that otosclerotic occlusion of the round window causes hearing loss comparable to fixation of the stapes.[161]

In this series I have encountered no cases of complete closure of the round window but have seen several cases of extremely small windows. Identification of otosclerotic foci at the periphery of the round window has not been possible under 16-power magnification, and these small windows observed are considered to be developmental. The size of the window seemed to have little to do with the clinical restoration of hearing in this series; however, it must be pointed out that no total closures were observed. Very large windows were occasionally seen, and a variety of membranes were

Figure 2

Photograph of a left tympanic cavity presented for the purpose of demonstrating variations of the stapedius muscle and its tendon

This stapedius tendon is seen in beautiful contrast Occasionally one sees the entire stapedius tendon and the pyramidal eminence without disturbing the chorda tympani nerve or the bony external canal This tendon is of average length and is inserted directly into the head of the stapes This tendon is parallel with the posterior crus, in its usual position

Observe the excessive vascularity of the mucous membrane

Figure 3

Photograph of a right tympanic cavity displayed for the purpose of showing a variation in the tendon of the stapedius muscle

The stapes is unusually large, as is the long process of the incus, yet the stapedius tendon is relatively small The tendon is inserted directly into the posterior crus of the stapes Although this variation is not uncommon, it is the most unusual point of insertion The neck and the head are the most frequent sites for stapedial tendon insertion

Usually, the tendon of the stapedius muscle is parallel to the posterior crus of the stapes, but in this ear it is deflected at almost a 45 degree angle inferiorly Even more uncommon than this position is that of a deviation of the tendon in a superior direction

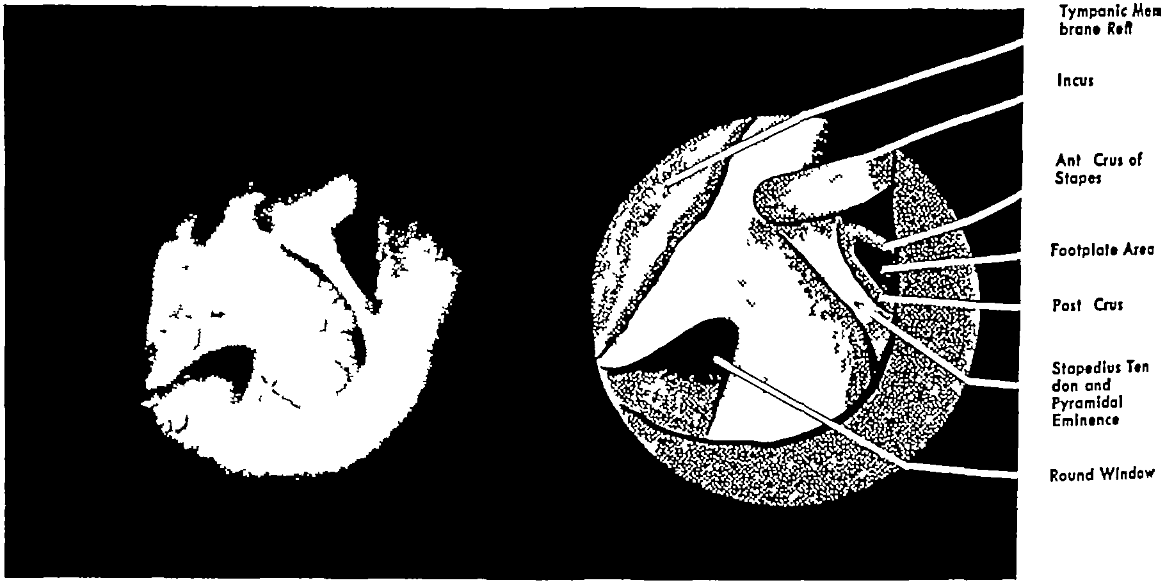
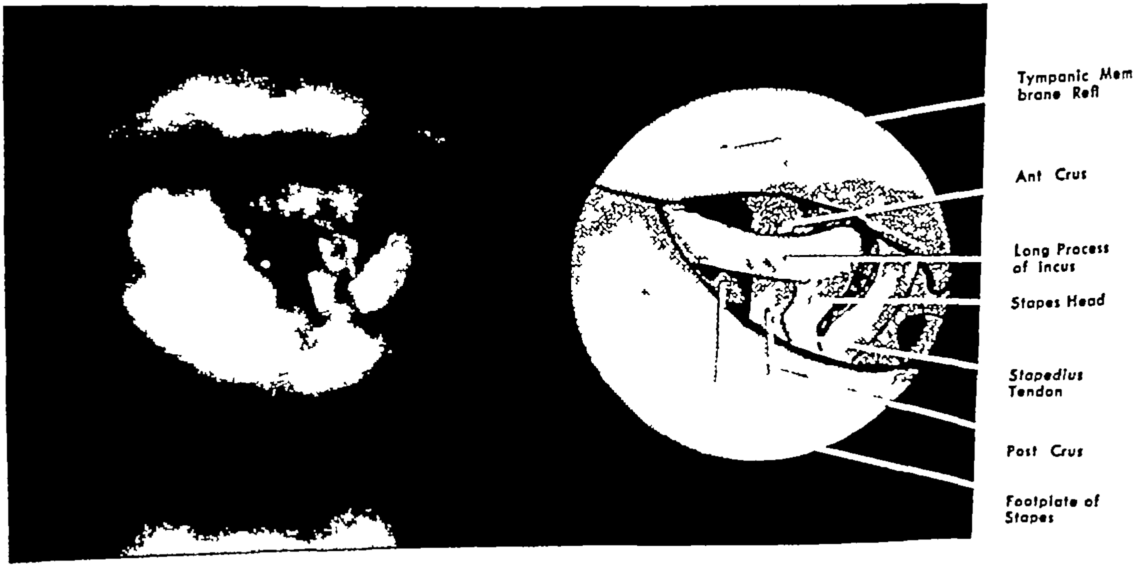


Figure 2



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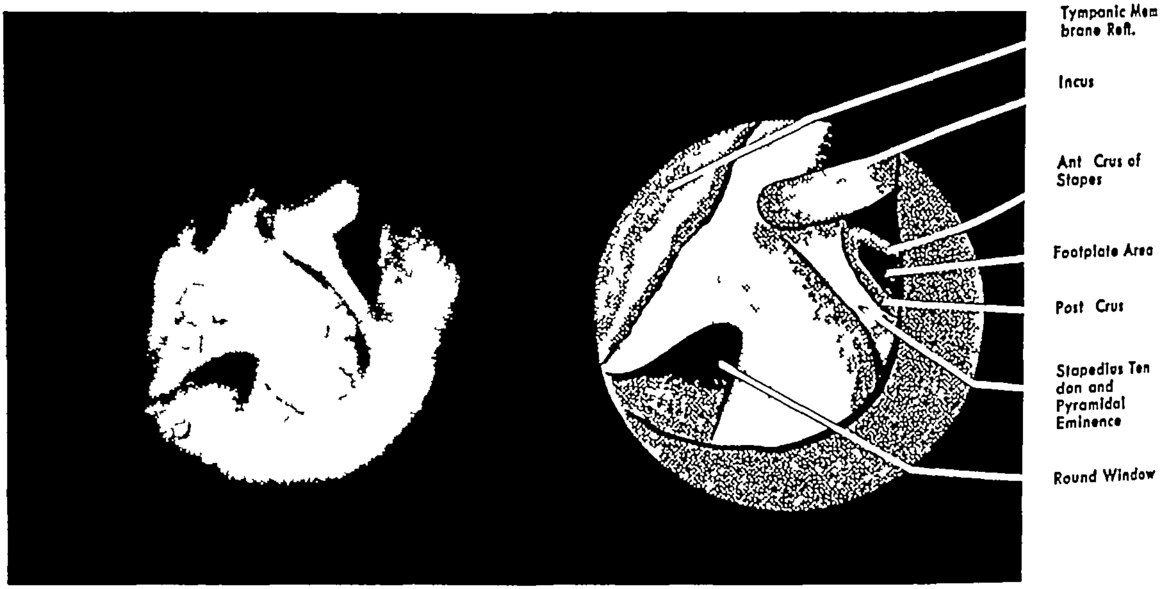


Figure 2

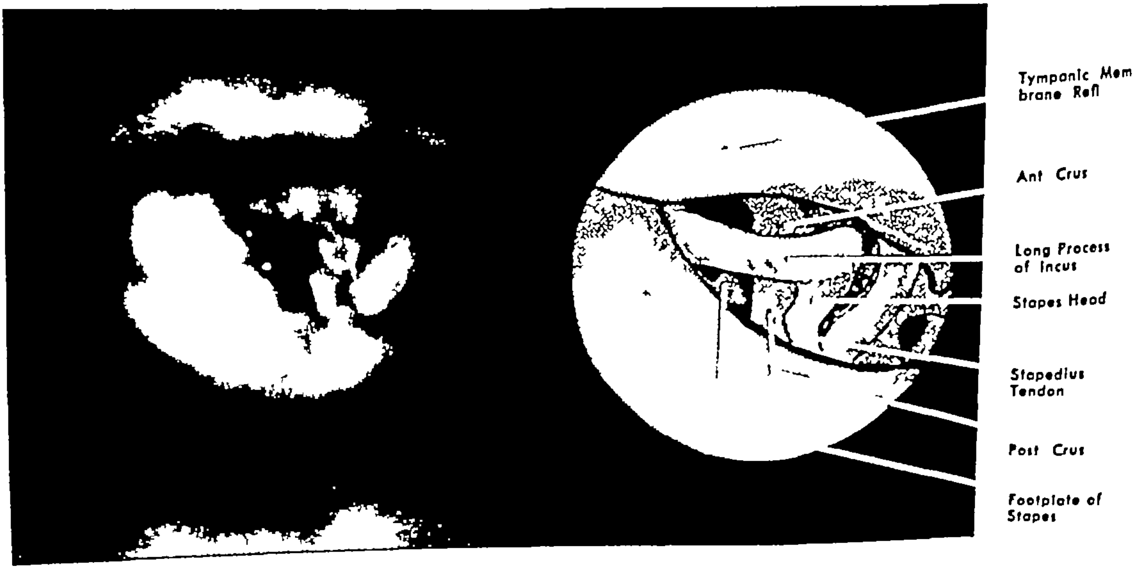


Figure 3

Figure 4

Photograph of a left tympanic cavity displayed for the purpose of showing bony and muscular variations

The long process of the incus describes an S-curve and articulates squarely with the head of the stapes

This stapes is extremely small, yet the crura are very thick An obturator foramen if present, is so small that a right angle pick could not palpate it, it could not be seen This stapes seems to be a rounded mass of bone in a very immature state Late in fetal life, the immature stapes is much larger than the mature stapes This apparent paradox is probably explained by the cessation of development in this patient somewhere between the 10th week (40 mm stage) and the 20th week (125 mm stage) of embryonic life

The footplate was present in this case but was likewise small and thick Fixation was apparently due to bony fusion to the margins of the oval window This was disrupted by mobilization maneuvers at the head of the stapes

Without the necessity of removing bone from the external canal wall, the pyramidal eminence is well seen, as is the bony ridge of the facial canal The pyramidal eminence is a continuation of the facial ridge in this ear This position and amount of projection is considered very unusual

Total absence of the stapedius muscle will be seen in Figure 5 This ear, however has an extremely short thick tendon It was so short that I first believed the stapes to be joined directly to the pyramidal eminence with bony union It was only after mobilization that I could see tendon motion

Figure 5

Photograph of a left middle ear displayed for the purpose of demonstrating muscular and bony malformations

This ear is an example of total absence of the stapedius muscle tendon, and its pyramidal eminence This is a deformity without evidence of other known head or neck malformations It was accompanied by fixation of the footplate of the stapes The problems encountered during the operation were no different from those seen in any other ear with ankylosis of the footplate margin

Much has been written concerning the function of the stapedius muscle. Five ears with congenital absence of this muscle are reported in this series In four of these patients serviceable hearing was obtained by operative restoration of mobility of the ossicular chain In none of the four cases were there symptoms which one might expect from either the loss of the so-called "protective mechanism" or the lack of the so-called "tuning-up ability," which has been ascribed to the stapedius muscle by some authorities This does not refute the theories of function of the stapedius muscle, but it establishes the fact that this muscle is not absolutely necessary for serviceable hearing Please see the pre- and post-operative audiogram of this patient following the discussion of Figure 28

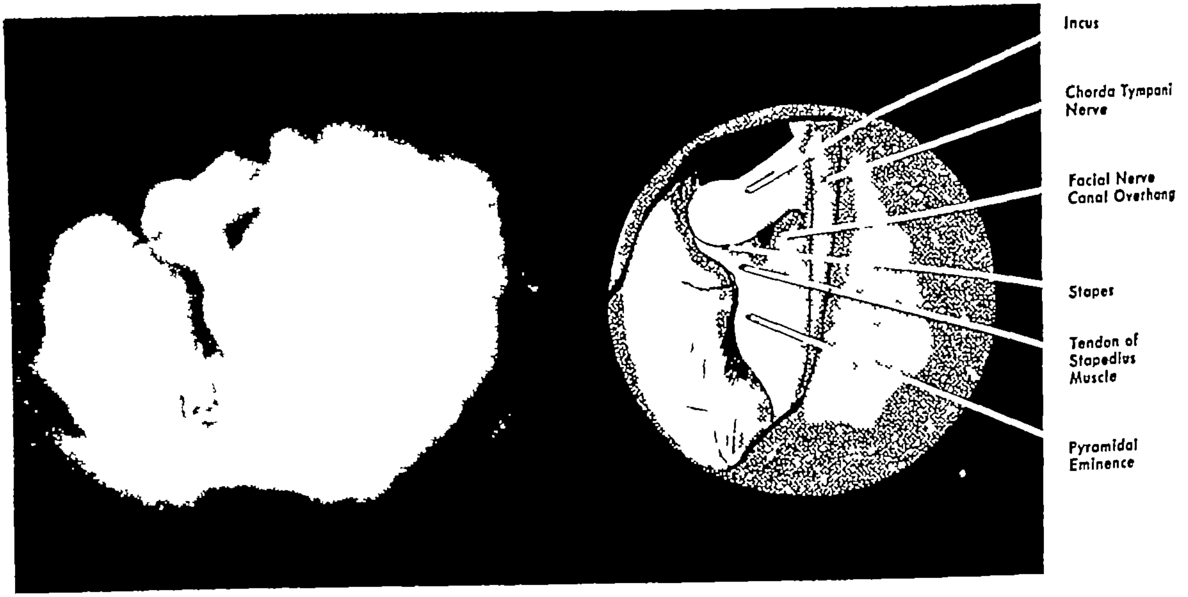
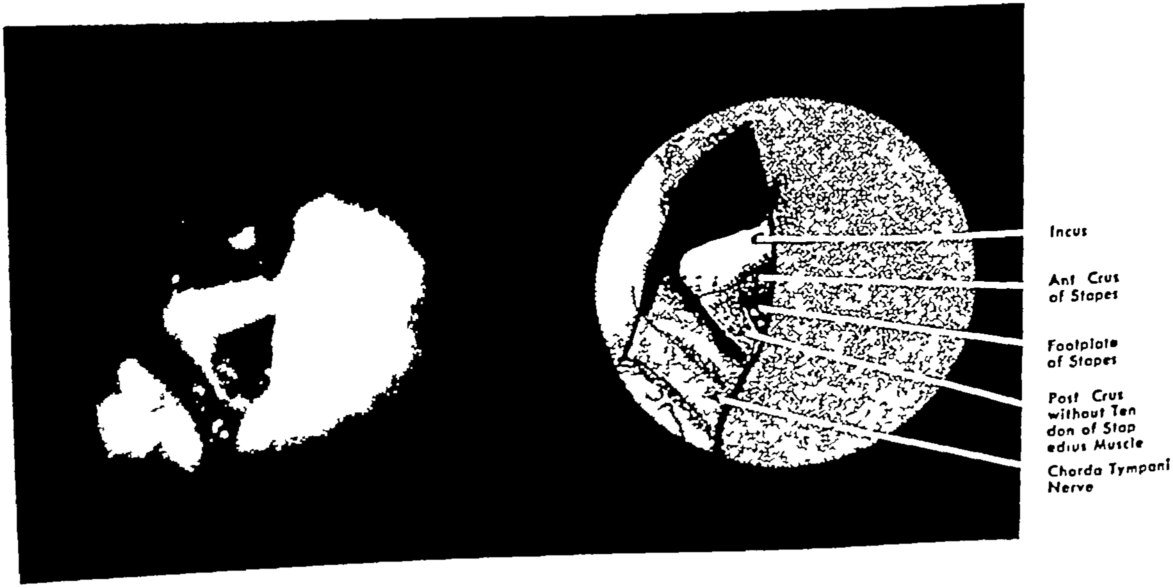


Figure 4



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This ear is an example of total absence of the stapedius muscle, tendon, and its pyramidal eminence This is a deformity without evidence of other known head or neck malformations It was accompanied by fixation of the footplate of the stapes The problems encountered during the operation were no different from those seen in any other ear with ankylosis of the footplate margin

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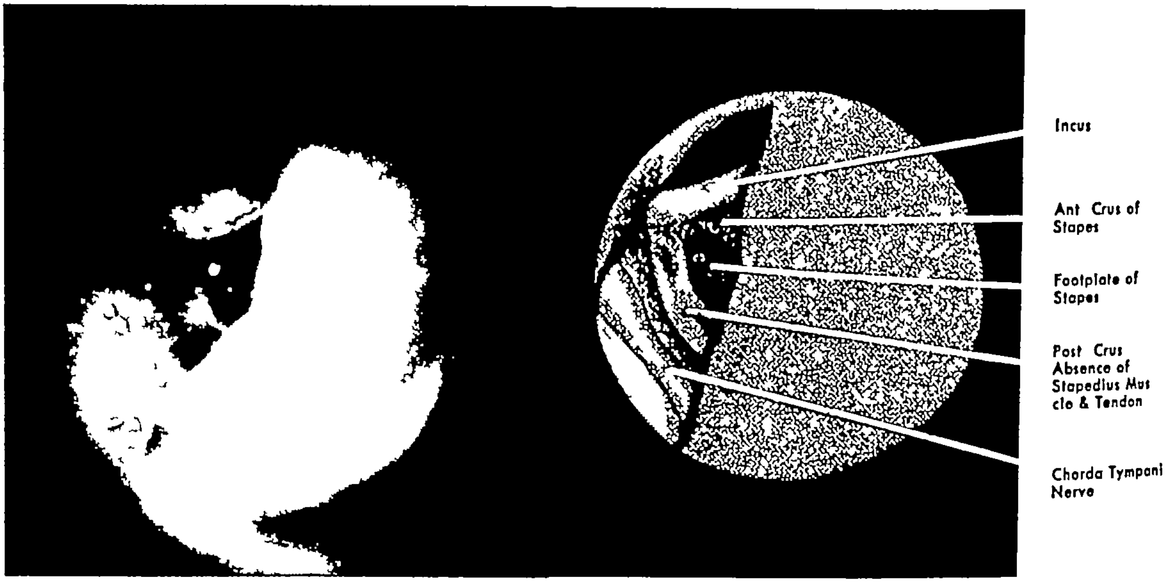

Figure 6

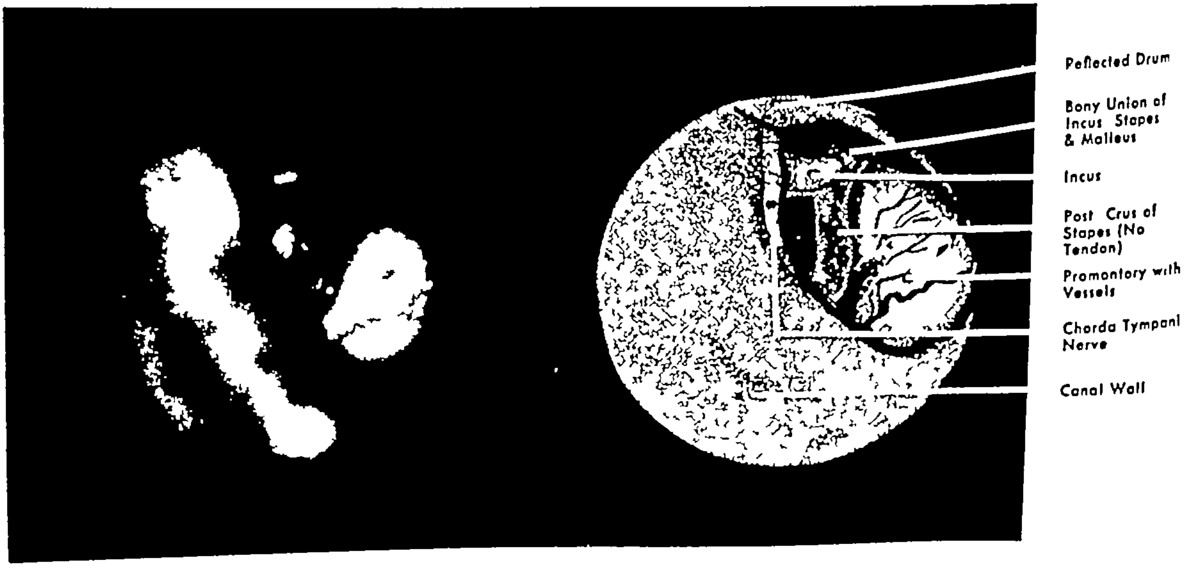

Figure 7

Figure 6

Photograph of a left middle ear displayed for the purpose of showing bony and muscular malformations

In this ear there was a bony union of the promontory to the inferior surfaces of the crura of the stapes There was a tremendous amount of longitudinal overgrowth of the long process of the incus

At operation, the crura of the stapes were gradually separated from the promontory and the stapes was made mobile For fear of possible re-attachment to the promontory, a repositioning of the incudostapedial joint was attempted The joint was purposely severed and the long process of the incus was shortened The head of the stapes was lifted superiorly so that its crura would not be against the promontory The head of the stapes was again made to rest on the inferior surface of the long process of the incus This questionable procedure proved to be worthwhile as shown by the ultimate functional result obtained Please see the pre- and post-operative audiograms reproduced following the discussion of Figure 30

The absence of the stapedius muscle, tendon, and its pyramidal eminence is again seen in this ear

Figure 7

Photograph of a right middle ear displayed for the purpose of showing bony malformations This ear also has a muscular abnormality and a variation in the position of the round window is seen

The rare malformation of triple bony union of the malleus, incus, and stapes is more clearly seen in Figure 8 and will be discussed there

The posterior crus of this stapes is clearly seen and is without its normal arch It is straight, but bends in a superior direction as it joins the footplate The posterior crus is not only without its normal arch but also is longer than the anterior crus

There is a total absence of the stapedius muscle, tendon, and pyramidal eminence in this ear This is one of five cases in this series with this abnormality To my knowledge, this abnormality has not been reported in ears without severe accompanying deformities The embryologic considerations will be given in the discussion of Figure 8

The footplate of the stapes is clearly seen just under the posterior crus The anterior crus of the stapes is hidden by the long process of the incus

Round window variations will be demonstrated in figures to follow, but an unusual variation in the position of the round window is here seen In this ear, the round window is almost completely hidden by the overhang of the bony external canal wall and is placed far posteriorly Without searching, one might be misled into believing that there is a total absence of the round window in this patient

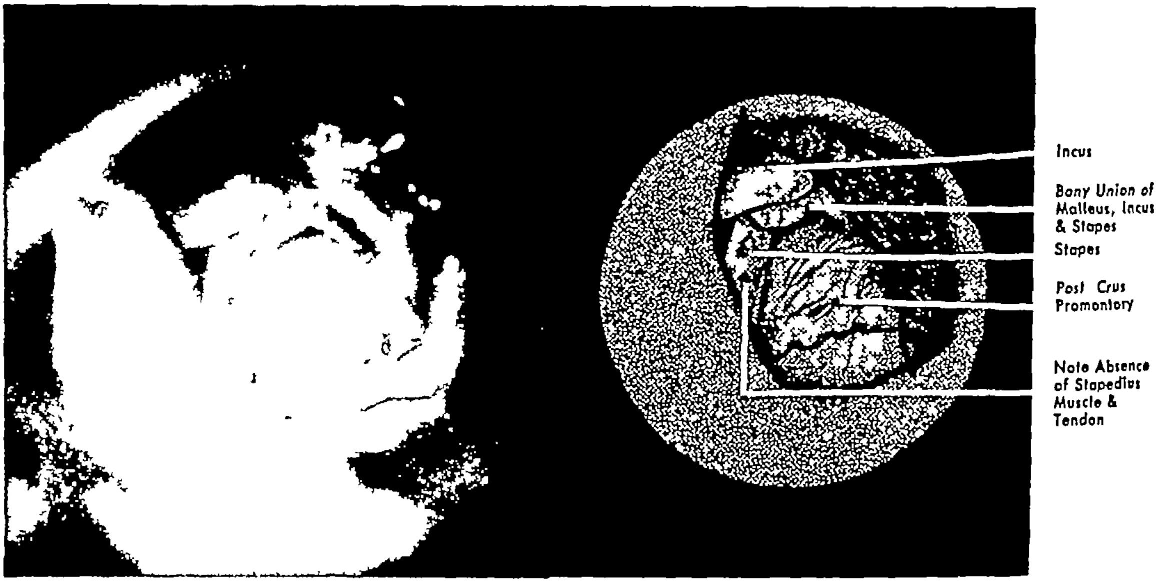
Incus
Bony Union of Malleus, Incus & Stapes
Stapes
Post Crus
Promontory
Note Absence of Stapedius Muscle & Tendon

Figure 8

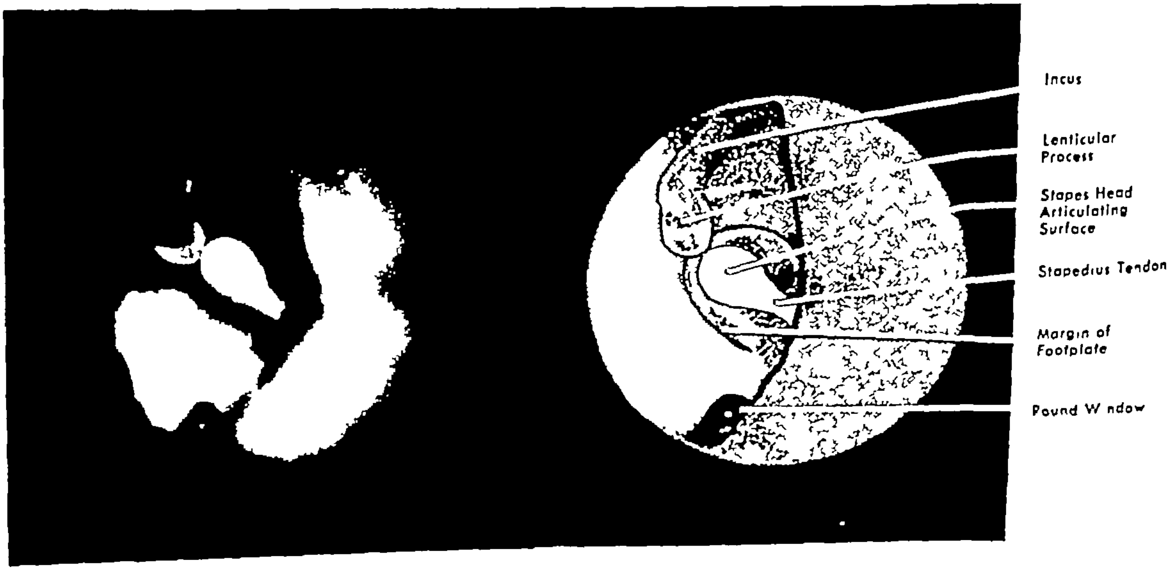
Incus
Lenticular Process
Stapes Head Articulating Surface
Stapedius Tendon
Margin of Footplate
Round Window

Figure 8

Photograph of the same ear as seen in Figure 7 presented for the purpose of demonstrating more clearly the bony malformations

This ear, as previously stated represents a rare triple bony union of the lenticular process of the incus with the handle of the malleus and the head of the stapes This deformity to my knowledge, has not been reported in the past. The long process of the incus is deformed presenting a twisted S-shape The handle of the malleus is clearly seen attached to the reflected tympanic membrane and is fused with the other two ossicles by a thick bony mass

The problem of micro-orthopedics is obvious Ossicular separation was accomplished and serviceable hearing was restored The discussion of proposed embryologic significance of this deformity may be seen directly following the presentation of photographs

Figure 9

Photograph of a left tympanic cavity displayed for the purpose of showing a rare skeletal anomaly involving complete disarticulation of the incus from the stapes

This patient suffered a severe blow upon his head during his youth and reported that partial loss of hearing in this ear began at that time No other symptoms are present and the opposite ear is functionally normal

Ossicular disarticulations due to nonfatal blows on the head have not been reported in the literature available to me One would therefore hold some reservation in stating that trauma is definitely the etiologic factor but due to the history it seems to be the most likely cause

Consideration must be given to the possibility of this being a congenital abnormality An embryologic explanation is difficult due to the absence of abnormalities in other structures closely related in development The incus is derived from the first visceral arch whereas the stapes is derived from the second visceral arch During the 8th week (23 mm stage) the lenticular process of the incus and the head of the stapes unite and a true articulating joint develops A variation in growth and development possibly could produce a non-union of these bones as seen above

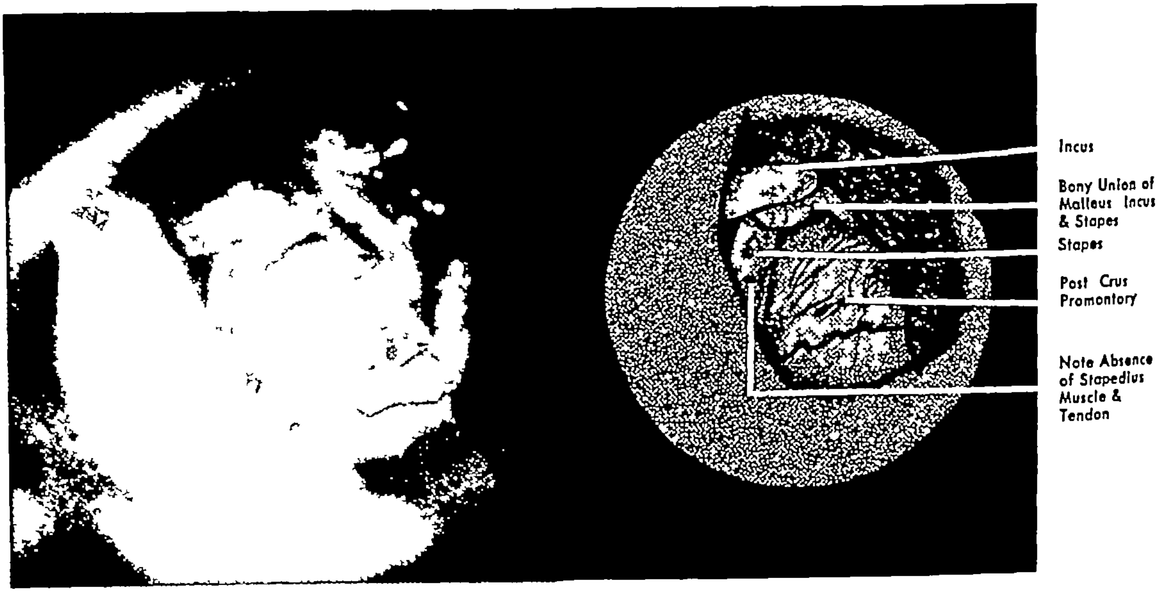
Incus
Bony Union of Malleus Incus & Stapes
Stapes
Post Crus
Promontory
Note Absence of Stapedius Muscle & Tendon

Figure 8

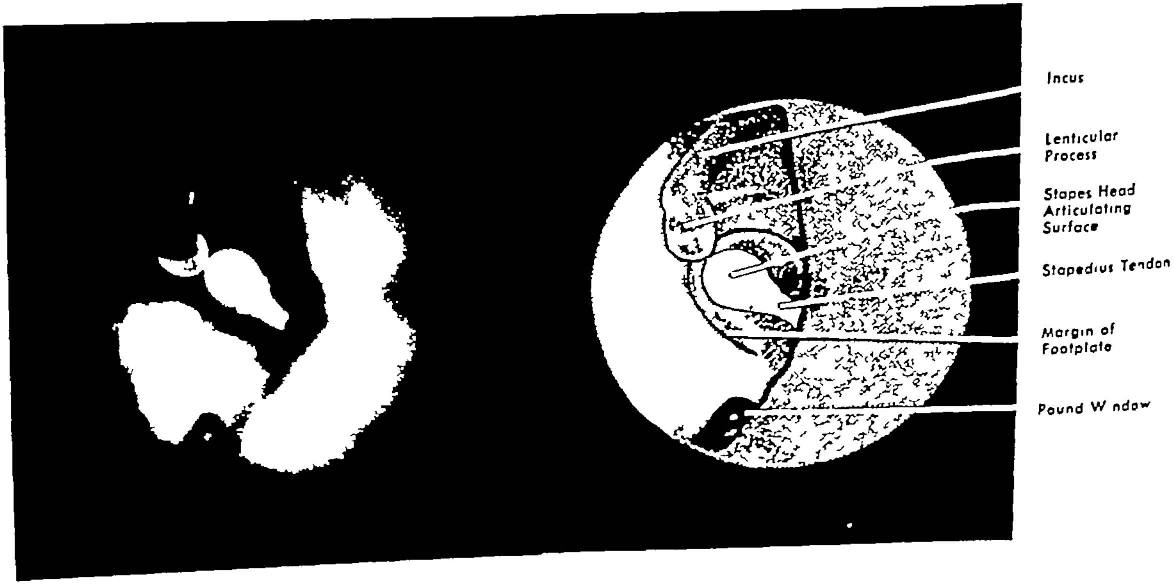

Figure 9

Figure 10

Photograph of a left middle ear (the same ear as reproduced in Figure 9) This brings the footplate of the stapes into better focus and demonstrates again the incudostapedial joint separation

This patient had a unilateral purely conductive hearing loss of 67 decibels for pure tone and 62 decibels for speech No other abnormalities of the middle ear could be found The round window was present and the membrane visible The malleus and incus were freely moveable The entire stapes was easily seen The footplate moved normally in the oval window There was no evidence of abnormalities of the external or internal ear which would account for the profound loss of hearing One may assume, with this evidence, that all of the hearing loss was due to disruption of the ossicular chain Many observers have suggested that sound reaches the cochlea by molecular transmission through the round window in the theory of "hearing in reverse" Other investigators have suggested that the cochlea receives sound by a universal transmission of energy by all of the surrounding tissues and air without any point of emphasis These theories deny the pre-eminence of transmission via the tympanic membrane and ossicular chain through the oval window to the cochlea Some observers ascribe only protective function to the tympanic membrane and ossicular chain It is not the purpose of this thesis to discuss theories of sound transmission, but the disarticulation presented in this patient caused consideration as to its functional significance

This cochlea had the opportunity to receive sound transmitted through either the round window or the oval window There was no mechanical barrier at either window Both avenues of entry were perfectly normal, yet there was a loss of 67 decibels for pure tone This type of hearing loss has been produced experimentally in animals by disruption of the ossicular chain continuity and testing cochlear potentials by the Wever-Bray phenomenon This patient, however, represents a human example of the sound transmitting ability of the ossicular chain Figure 11 will demonstrate a return of that function in the same patient by restoration of the ossicular chain

Figure 11

Photograph of the same left tympanic cavity as seen in Figures 9 and 10, displayed for the purpose of demonstrating operative correction of the incudostapedial joint separation previously seen

The articulating surfaces of the head of the stapes and the lenticular process of the incus were roughened by the use of small picks A small shaving of bone was removed from the edge of the bony external canal wall and teased into position between the articulating surfaces of the two ossicles The hearing was instantly restored to normal and there was no regression in six months Please see audiogram of this patient directly following the presentation of photographs

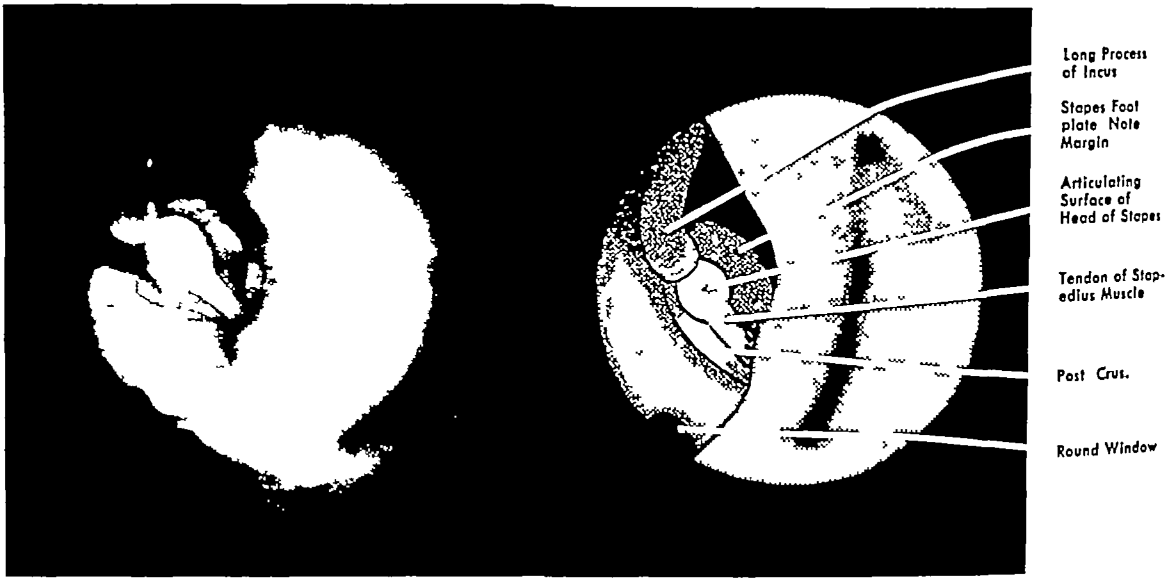
Long Process of Incus
Stapes Foot plate Note Margin
Articulating Surface of Head of Stapes
Tendon of Stapedius Muscle
Post Crus.
Round Window

Figure 10

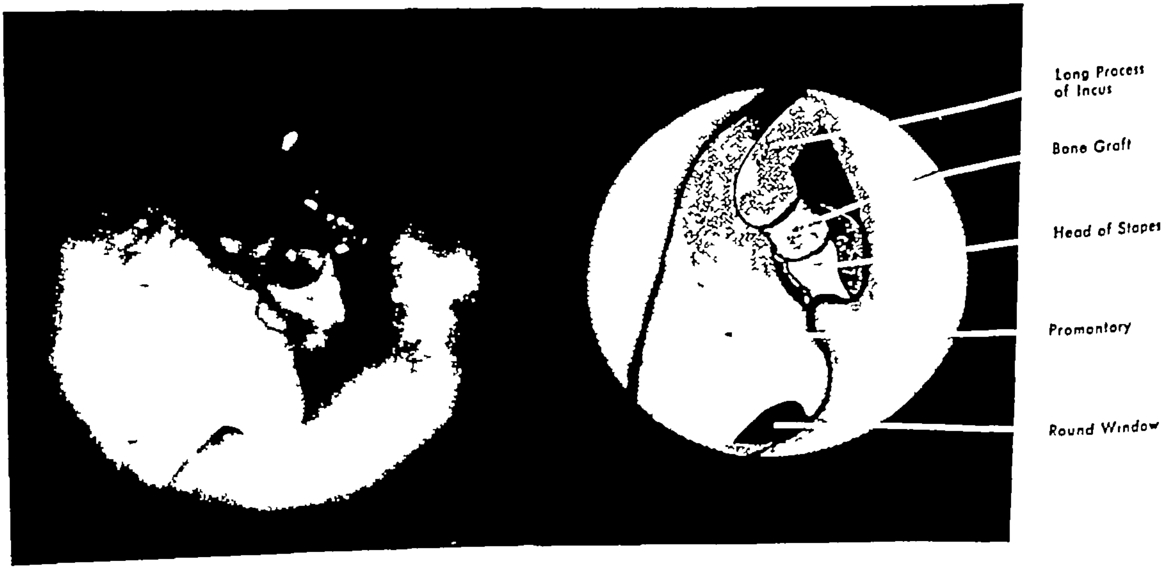

Figure 11

Figure 14

Photograph of a right tympanic cavity seen in Figure 13 after removal of mesenchymal tissue strands

The two crura of the stapes can be seen wrapped around the facial canal like the claws of a bird on a limb The crura are bony but are extremely fragile The are rounded off as they meet a very indefinite footplate The oval window area is apparently recessed high up beneath the bony ridge of the facial nerve There is a total absence of an oval window A total absence of the oval window has been considered extremely rare In literature available to me there were no human cases reported of this abnormality during the past 100 years An attempt was made in this ear to find the oval window with the use of sharp probes but only solid bone was encountered

The stapedius tendon and pyramidal eminence are easily seen, but are very small

A large bony spicule is seen projecting from the annulus to the promontory

This malformation would have been overlooked and misdiagnosed without trans-aural tympanotomy This patient's deafness has been considered to be due to a variety of conditions such as hypertrophy of the tonsils and adenoids Eustachian tube obstruction on the basis of allergy adhesive otitis media and congenital perceptive deafness This patient had undergone tonsillectomy and adenoidectomy radium application to the nasopharynx Eustachian tube insufflation and allergic management for the relief of deafness The microscopic examination of this middle ear presented a correct diagnosis and initiated the planning of a rational surgical procedure for restoration of hearing

Figure 15

Photograph of a right tympanic cavity displayed for the purpose of demonstrating marked congenital malformations of the ossicles

This is an ear of a 7 year old girl with a purely conductive deafness present presumably since birth.

The incus appears fairly normal but its body apparently placed more anteriorly than usual

The head of the stapes has been purposely disarticulated and rotated posteriorly so that the posterior crus and the footplate area are in view

There is a total absence of the anterior crus of the stapes in this ear In animals, malformed unicurate, or columelliform, stapedes have been reported, but this is the first unicurate human stapes reported as far as I can determine, without accompanying external or inner ear deformities

The footplate of the stapes is not present, but in its place is solid otic capsular bone There is no oval window due to the lack of differentiation of the lamina stapedialis described in the embryologic discussion of Figures 13 14 15, and 16 The end of the posterior crus is clearly seen in the photograph Audiometric findings of this patient may be seen directly following the presentation of photographs

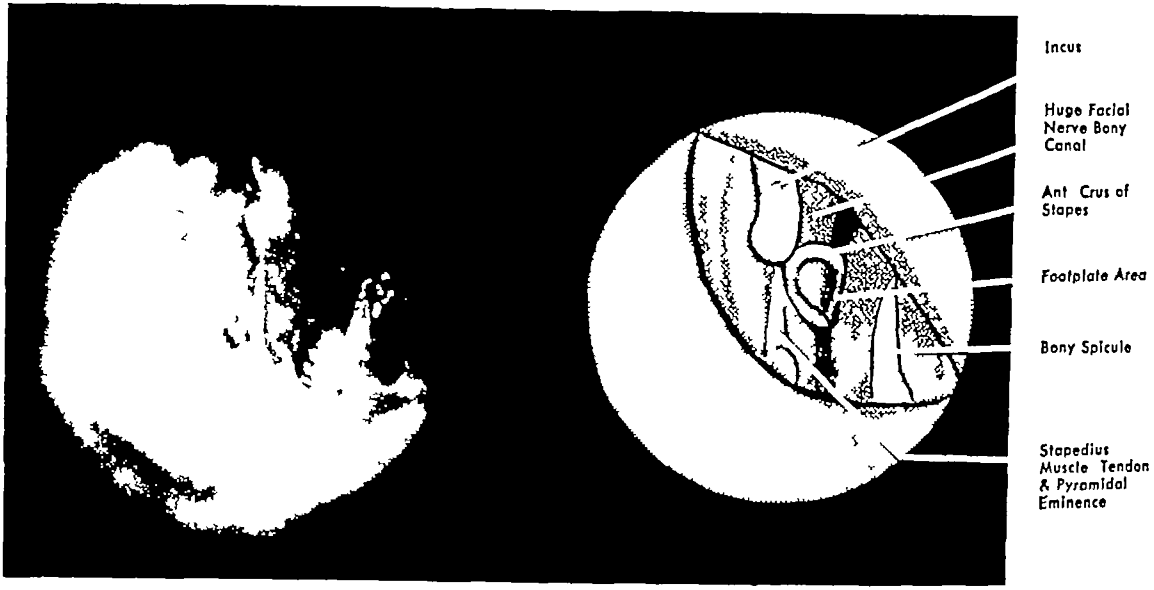
Incus
Huge Facial Nerve Bony Canal
Ant Crus of Stapes
Footplate Area
Bony Spicule
Stapedius Muscle Tendon & Pyramidal Eminence

Figure 14

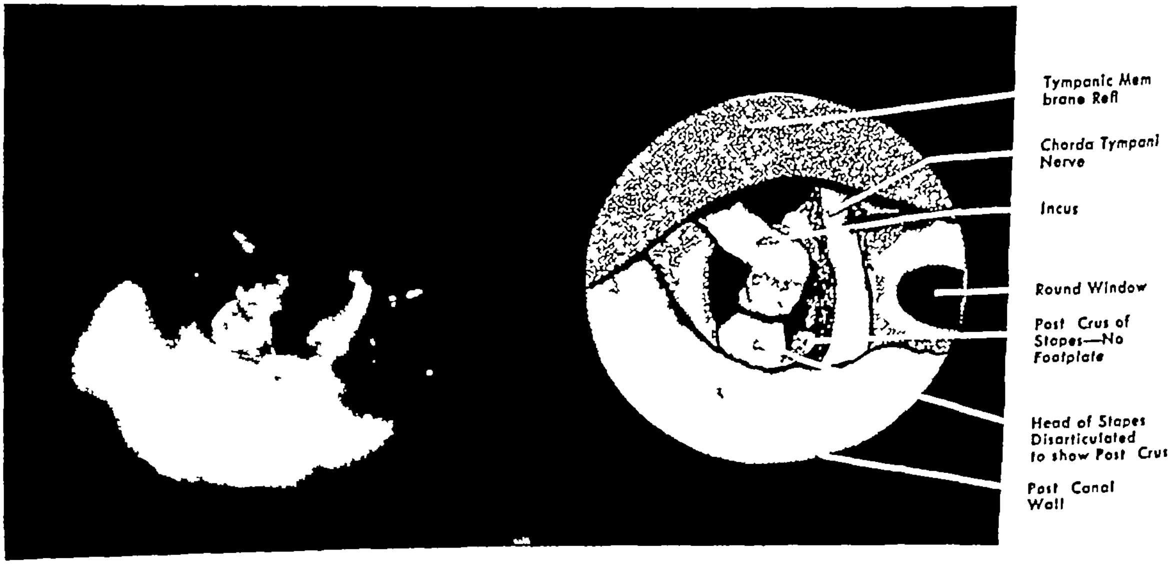
Tympanic Mem brane Refl
Chorda Tympani Nerve
Incus
Round Window
Post Crus of Stapes—No Footplate
Head of Stapes Disarticulated to show Post Crus
Post Canal Wall

Figure 14

Photograph of a right tympanic cavity seen in Figure 13 after removal of mesenchymal tissue strands

The two crura of the stapes can be seen wrapped around the facial canal like the claws of a bird on a limb The crura are bony, but are extremely fragile The are rounded off as they meet a very indefinite footplate The oval window area is apparently recessed high up beneath the bony ridge of the facial nerve There is a total absence of an oval window A total absence of the oval window has been considered extremely rare In literature available to me there were no human cases reported of this abnormality during the past 100 years An attempt was made in this ear to find the oval window with the use of sharp probes, but only solid bone was encountered

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This malformation would have been overlooked and misdiagnosed without trans-aural tympanotomy This patient's deafness has been considered to be due to a variety of conditions, such as hypertrophy of the tonsils and adenoids, Eustachian tube obstruction on the basis of allergy, adhesive otitis media, and congenital perceptive deafness This patient had undergone tonsillectomy and adenoidectomy, radium application to the nasopharynx Eustachian tube insufflation, and allergic management for the relief of deafness The microscopic examination of this middle ear presented a correct diagnosis and initiated the planning of a rational surgical procedure for restoration of hearing

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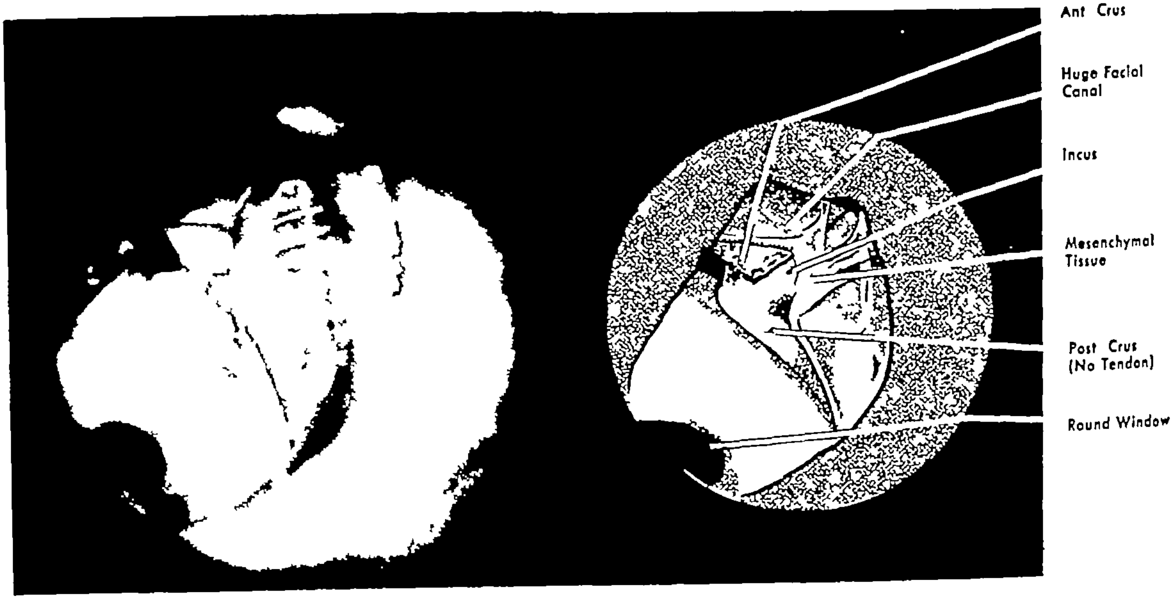


Figure 16

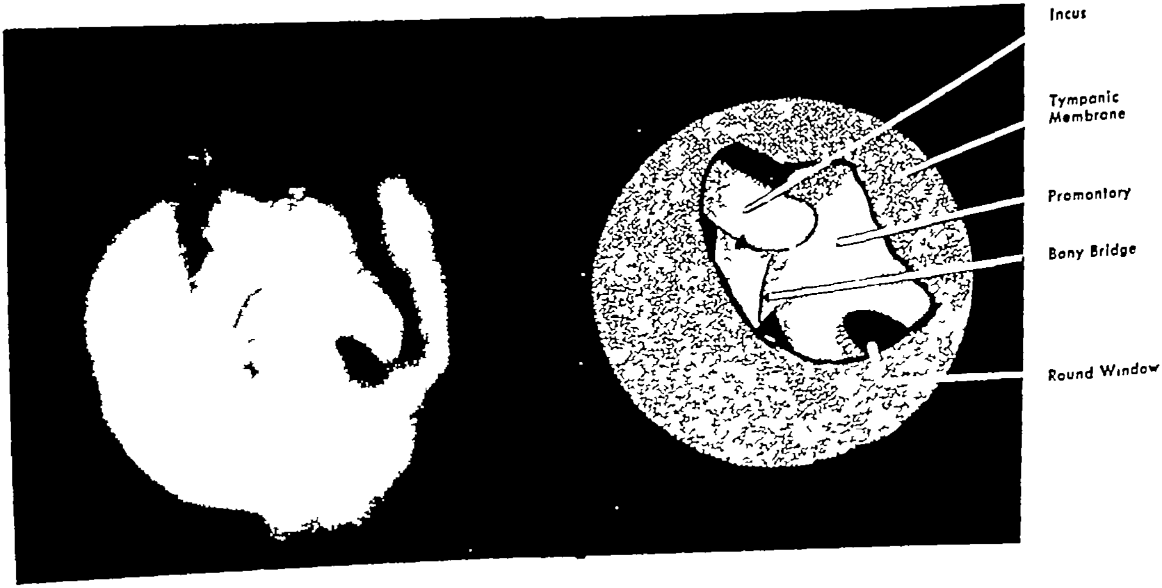


Figure 17

Figure 16

Photograph of a left tympanic cavity displayed to show marked bony malformation and absence of the stapedius muscle and tendon

This is another ear representing a congenital conductive deafness without accompanying external or internal ear malformations

There is a total absence of the stapedius muscle, tendon, and pyramidal eminence

The long process of the incus articulates with the poorly developed head of the stapes The anterior and posterior crura of the stapes are easily seen disappearing into a very narrow niche between the bulge of the bony facial canal and the promontory The crura are very small and end as free stumps in the area of the oval window

This is the third ear with complete congenital absence of the oval window reported in this series There is no evidence in this ear of differentiation of the lamina stapedialis and the surrounding capsular area into a footplate for the stapes or an oval window

The report of these cases lends evidence to the theory that the stapes footplate is derived from both the second visceral arch and the otic capsule

The bony canal for the facial nerve is extremely large in this ear and one can see strands of mesenchymal tissue superficial to it

Trans-aural tympanotomy was necessary for a correct diagnosis in this patient A bypass of the oval window area by the creation of another labyrinthine fenestra will be necessary in order to improve this patient's hearing

Figure 17

Photograph of a right middle ear displayed for the purpose of showing a bridge of bone

A projection of a bony process from the promontory to the area of the facial nerve, or pyramidal eminence, is very common This ear demonstrates, perhaps, a larger than usual example of this bony variation This process is frequently so near the posterior crus of the stapes that bony union is considered to be present It has been my experience that usually, as was true in this case, there will be no union, although sometimes this process makes a true bridge across this area

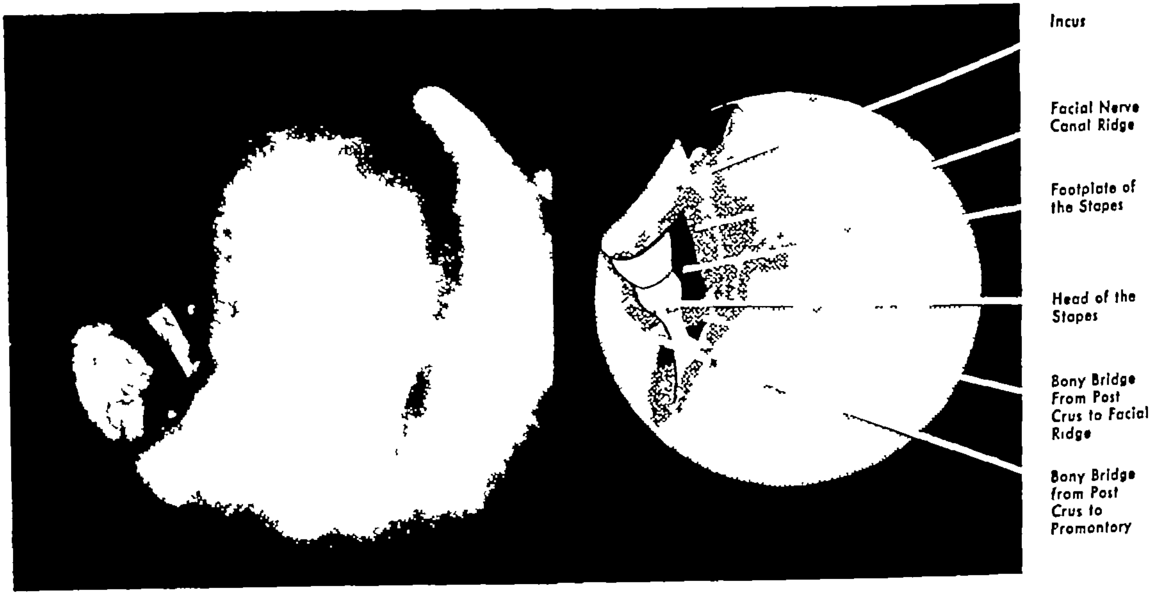

Incus
Facial Nerve Canal Ridge
Footplate of the Stapes
Head of the Stapes
Bony Bridge From Post Crus to Facial Ridge
Bony Bridge from Post Crus to Promontory

Figure 18

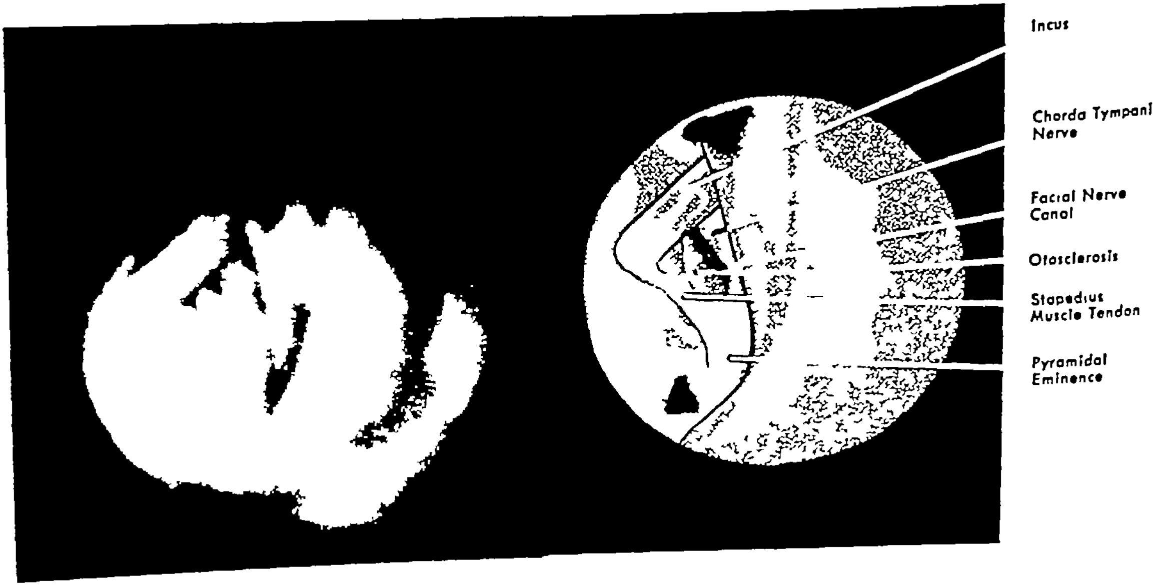


Figure 19

Figure 18

Photograph of a left middle ear displayed for the purpose of showing *bridges of bone producing fixation of the stapes Also seen is a narrow* and deep niche for the stapes, and a stapedial head with an unusual shape

A very high promontory, which bulges superiorly, has produced a very narrow deep niche for the stapes A small bony process extends from the promontory to the posterior crus of the stapes Another bridge of bone extends from the posterior crus to the bulge of the bony facial canal Lysis of these bridges can be accomplished if good exposure can be obtained

Figure 19

Photograph of a left middle ear displayed for the purpose of showing a large amount of otosclerotic overgrowth It also demonstrates an extremely short stapedius tendon, an exceptional view of the pyramidal eminence, and an unusual view of the ridge of the facial nerve canal

In this ear, otosclerotic bone has completely filled the niche for the stapes Masses of it have covered most of the crura so that only the head of the stapes seems to remain uncovered The footplate and crural landmarks have been lost

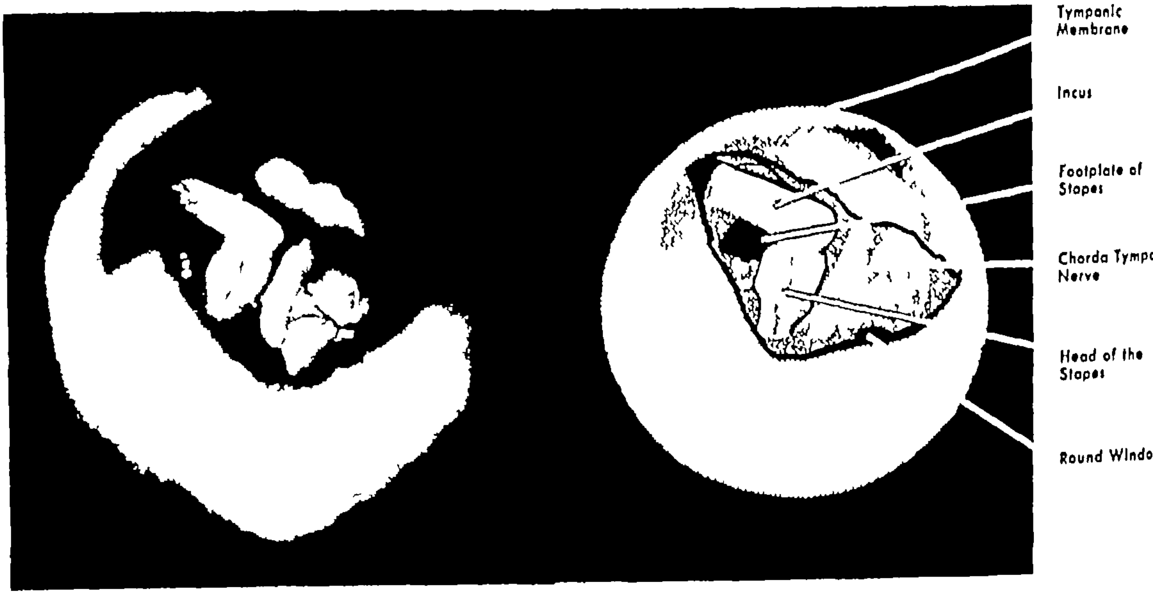

Tympanic Membrane
Incus
Footplate of Stapes
Chorda Tympa
Nerve
Head of the Stapes
Round Windo

Figure 20

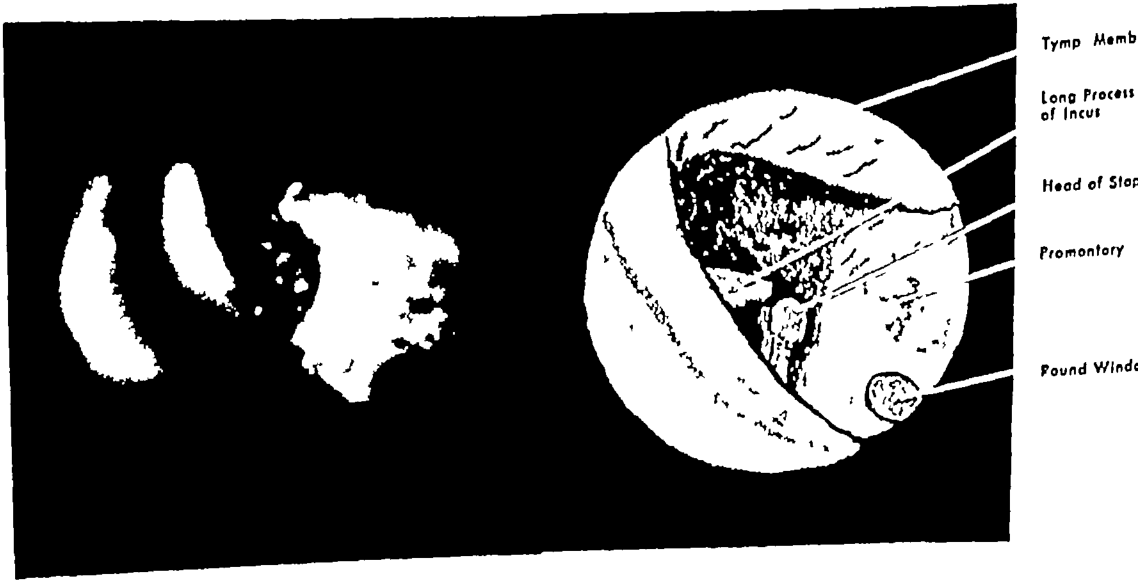

Tymp Memb
Long Process of Incus
Head of Stap
Promontory
Round Windo

Figure 20

Photograph of a right tympanic cavity showing a usual view of the long process of the incus, head of the stapes, and footplate following the elevation of the chorda tympani nerve from its bed This is shown for comparative purposes

The incus is articulating with the head of the stapes in the most usual slightly anterior position The lenticular process is well formed and appears normal The long process of the incus is slightly curved medially and posteriorly and has no rough ridges on its lateral surface The articulating surfaces are in a plane fairly square with the head of the stapes and footplate, permitting pressure, if necessary, through the incus on the stapes for mobilization purposes

The amount of bony overhang of the canal seen in this ear is normal

The footplate of the stapes is partially obscured by the thin cob-web strands of mesenchymal tissue This is a common finding

The tendon of the stapedius muscle inserts normally into the head of the stapes

Figure 21

Photograph of a right tympanic cavity displayed for the purpose of showing a variation in the long process of the incus

This ear demonstrates an absence of the lenticular process of the incus, perhaps from necrosis There is a noticeable lack of scar tissue in the middle ear The tympanic membrane is normal in this ear and there was no past history of middle ear disease given by the patient Nevertheless, one must consider the strong possibility of inflammatory disease producing such a picture

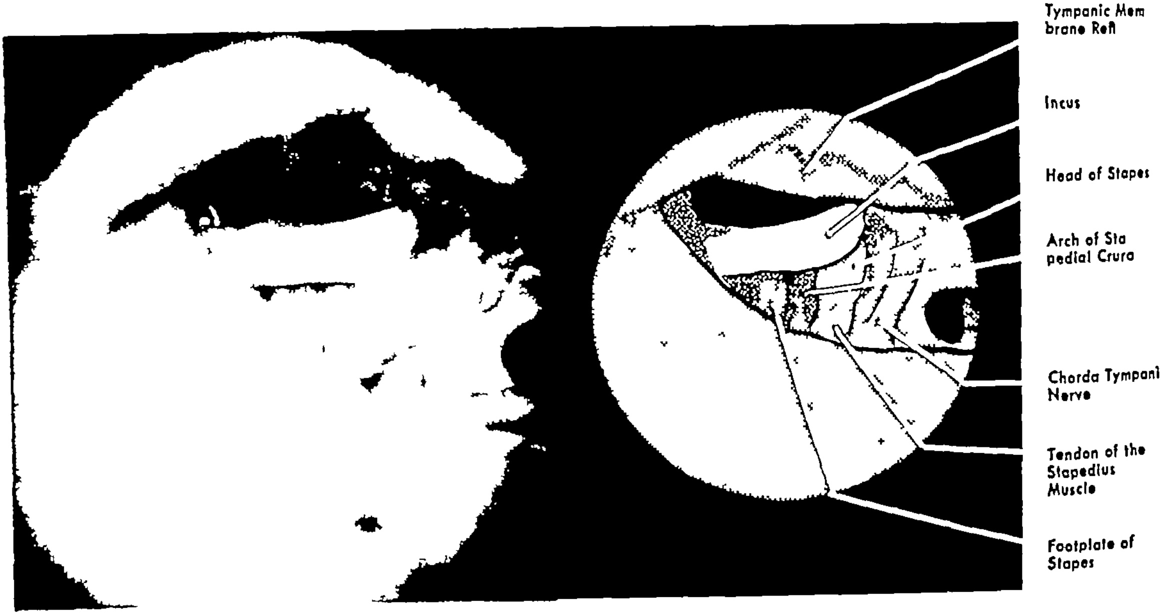


Figure 22

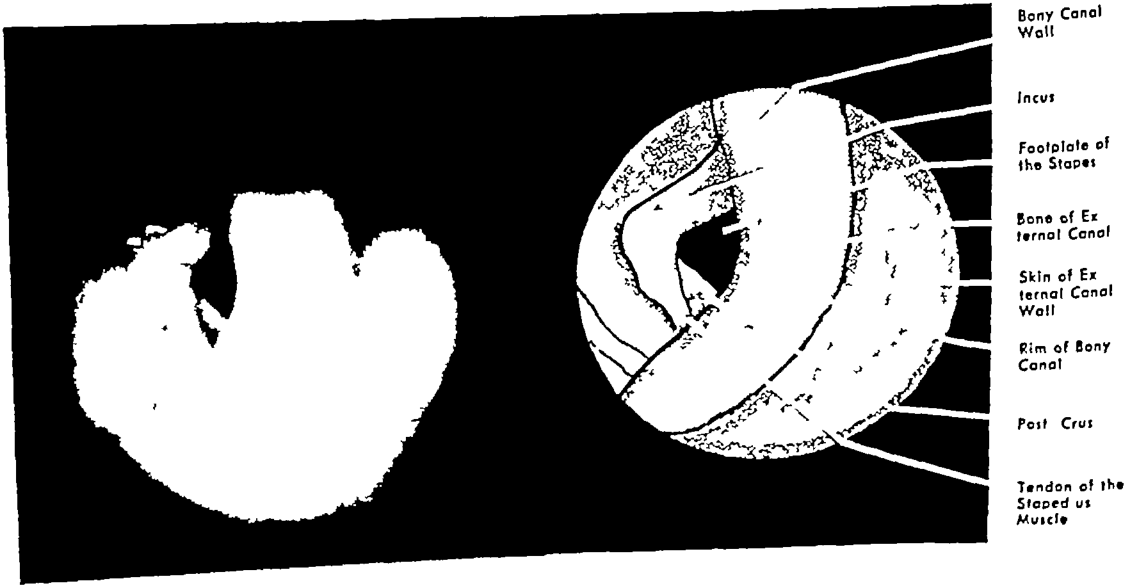


Figure 23

Figure 22

Photograph of a right middle ear presented for the purpose of showing variations in the long process of the incus

The long process of the incus becomes visible at a lower level in this ear and points more directly inferiorly than usual The most striking feature of this process of the incus is its length The shaft is bowed, causing it to appear comma-shaped It is turned upward at the end somewhat like the bow of a ship Despite its length, it does not extend too far beyond the head of the stapes and its articulating surface even faces somewhat inferiorly This articulating surface must be considered if pressure through the incus is to be exerted on the stapes for the purpose of mobilization If the direction and pressure are faulty, dislocation is likely to occur

The footplate of the stapes is clearly seen and is apparently infiltrated with otosclerotic bone The crural arch of this stapes is extremely large

Figure 23

Photograph of a left tympanic cavity presented for the purpose of demonstrating variations

The long process of the incus is turned medially at its tip and is rounded at this extremity Articulation with the head of the stapes is far anterior, but the articulating surface is tilted only slightly anteriorly

The tendon of the stapedius muscle is inserted into the small neck of the stapes These findings are not considered unusual but are variations within the range of normal

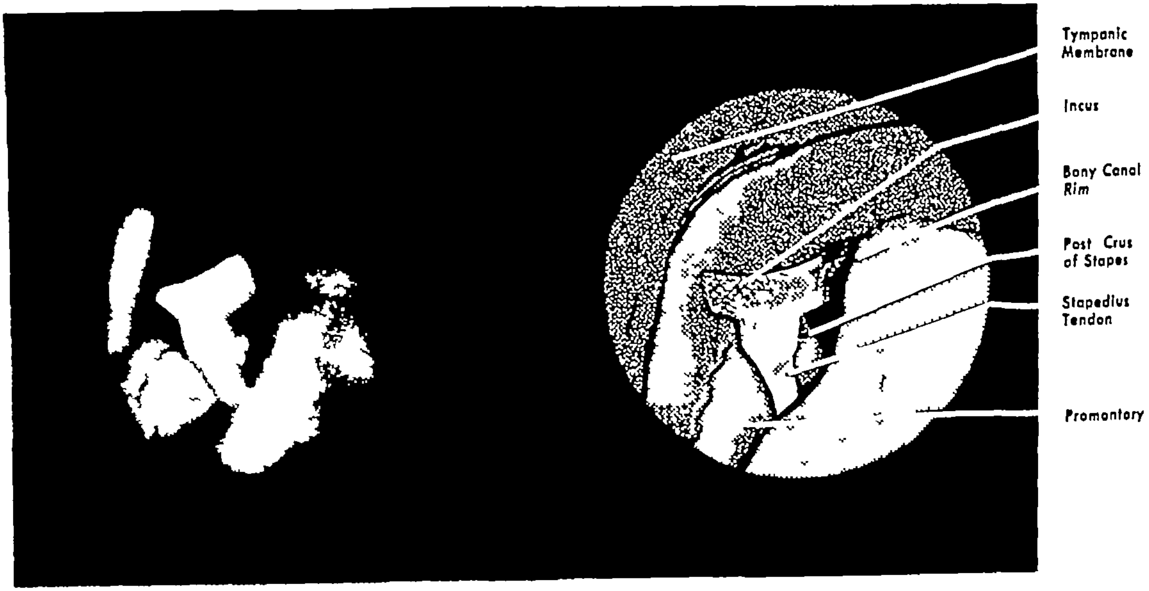


Figure 24

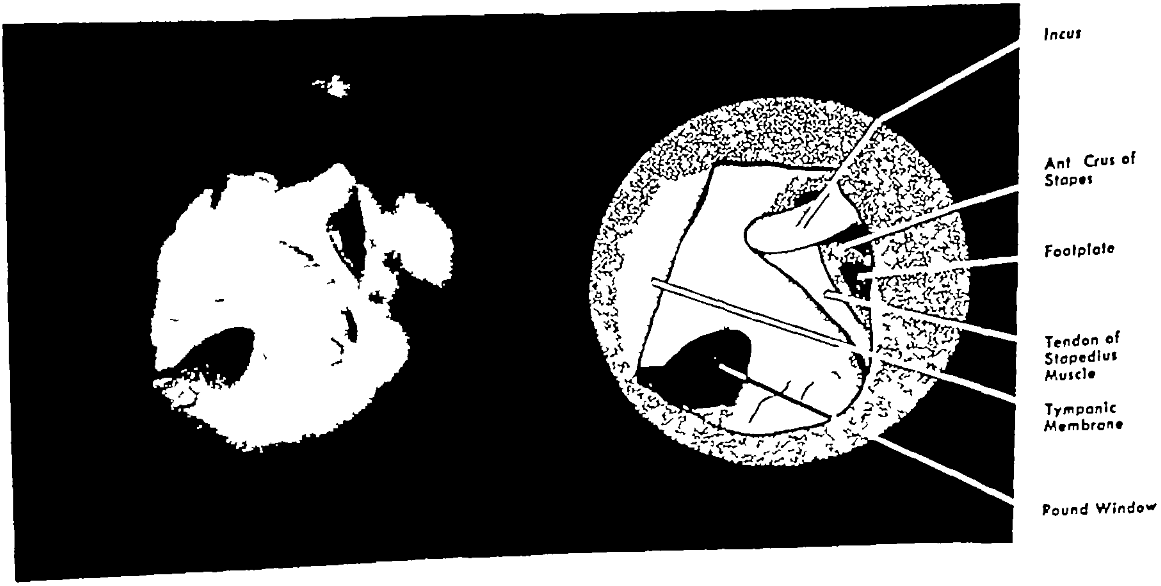


Figure 25

Figure 24

Photograph of a left tympanic cavity presented for the purpose of demonstrating variations in the long process of the incus

The long process of the incus has a sharp bony projection on its lateral surface in this ear This turns up like the bow of a ship, and presents a rough lateral surface which must be considered if instrumentation is to be done in this area The lenticular process of the incus articulates with the head of the stapes in its usual slightly anterior location The stapedius tendon inserts into the head of the stapes from an inferior direction thus exposing the posterior crus

Figure 25

Photograph of a left tympanic cavity presented for the purpose of showing variations in the long process of the incus

This view is not uncommon, but shows an uptilted long process of the incus in comparison to the slight medial downward turn seen in Figure 23

The head of the stapes is placed far forward and the lenticular process of the incus is resting on its posterior aspect The long process of the incus actually hides from view the head of the stapes Please compare with Figure 24

The stapes is tilted inferiorly and, therefore, the articulating surface is angulated This position must be considered before pressure is attempted through the incus if a mobilization of the stapes is contemplated

The stapedius tendon is exceptionally well seen without disturbance of the chorda tympani nerve or the bony external canal The tendon inserts high on the head of the stapes in this ear

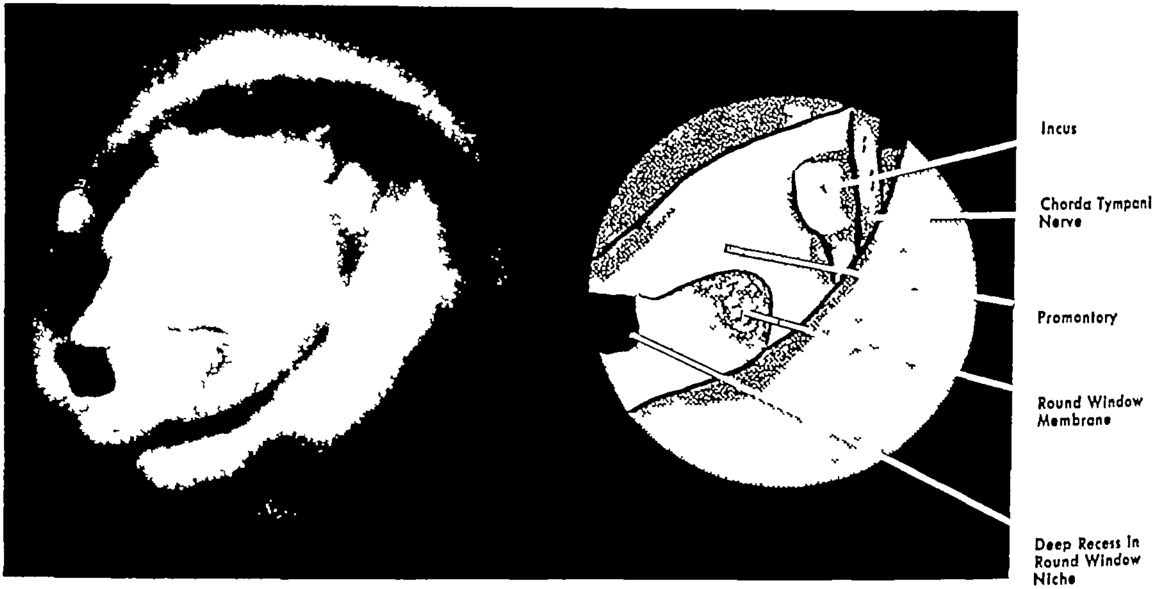


Figure 26

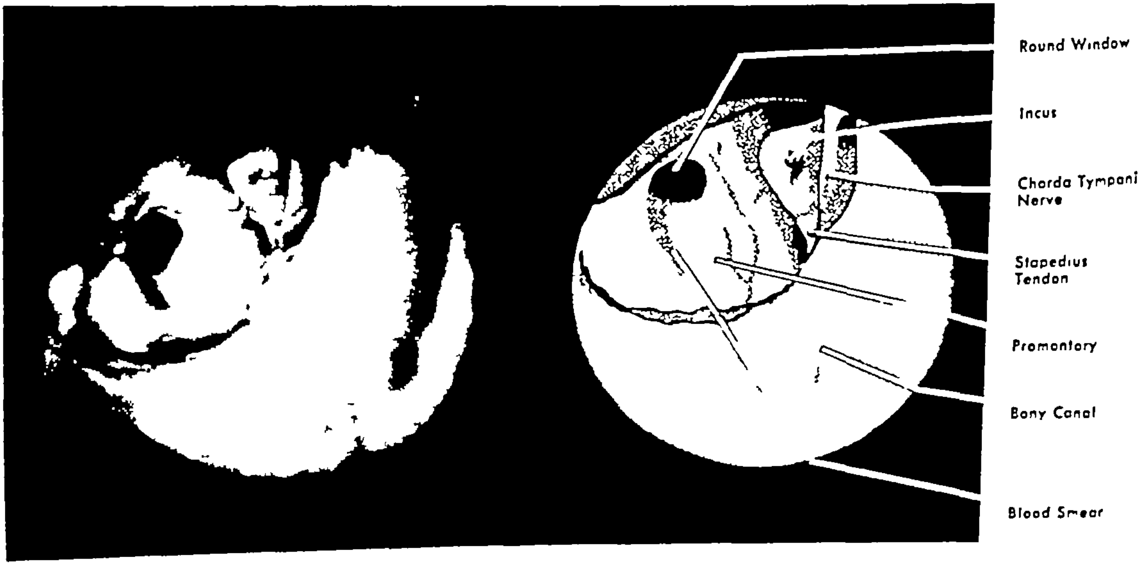


Figure 27

Figure 26

Photograph of a left middle ear displayed for the purpose of showing *round window variations*

This round window membrane is seen clearly and is facing in the posterior, inferior and lateral direction It is also on the usual posterior, inferior aspect of the promontory A large wide niche is present and a very deep depression, or second window, is present at its inferior margin I believe that most of the deep depressions commonly seen in this location are rarely in direct communication with the labyrinth

Figure 27

Photograph of a left middle ear displayed for the purpose of showing round window variations

This round window is without a niche and is situated unusually far anteriorly It is actually as far anterior as the oval window The membrane is facing posteriorly, laterally, and slightly superiorly The window is placed on the summit of the promontory

This photograph also shows the usual view of the incus seen on lifting the tympanic membrane The area hidden by the chorda tympani nerve, the moderate amount of bony overhang, and the barely visible stapedius tendon is considered to be average exposure of the middle ear

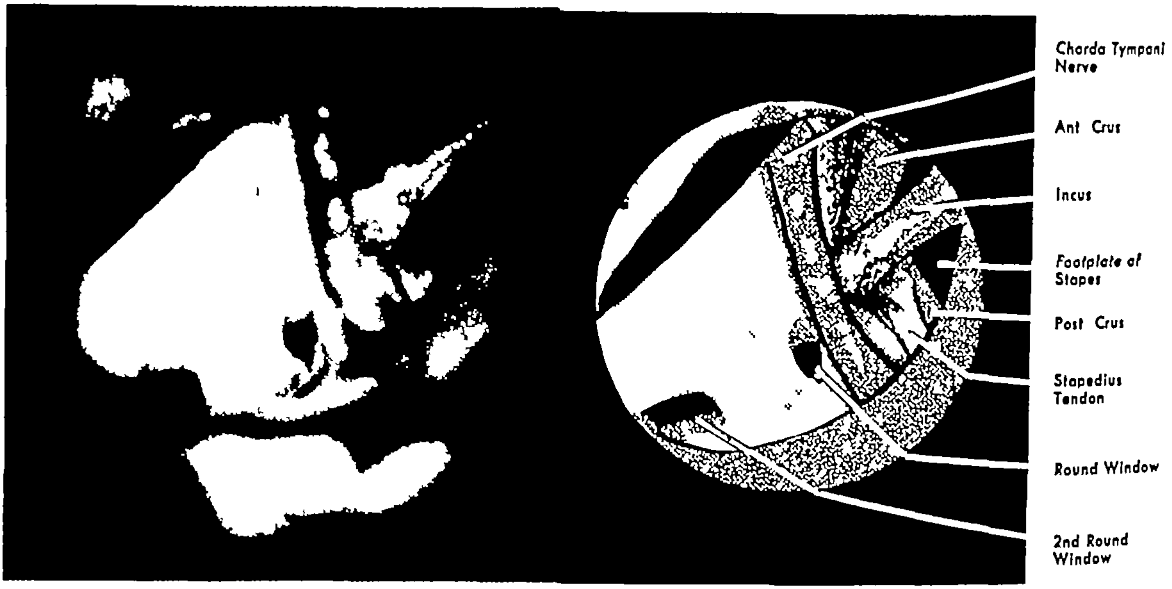


Figure 28

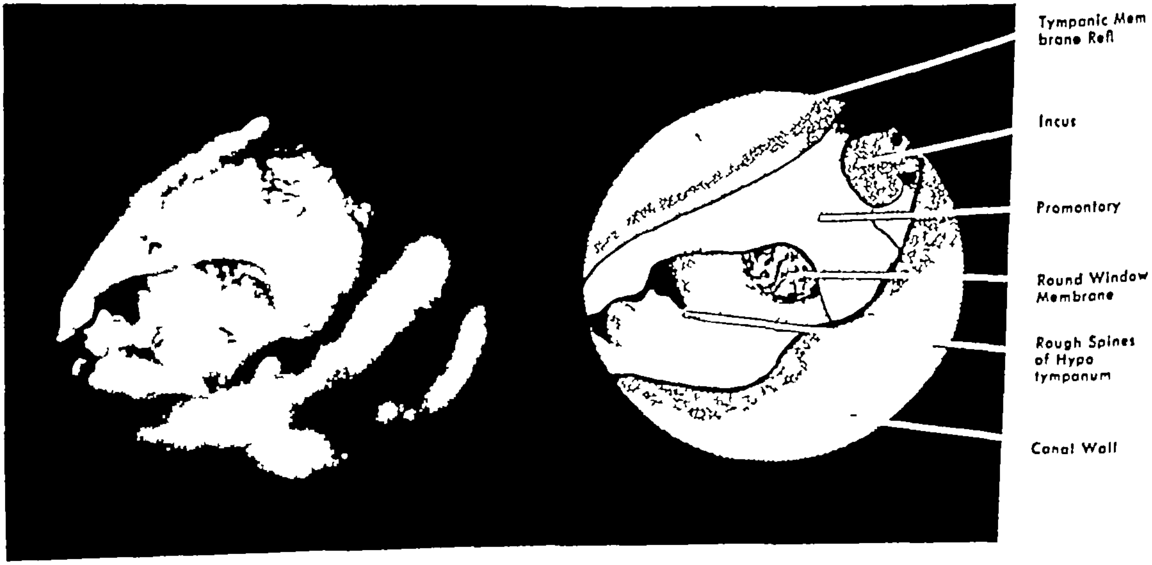


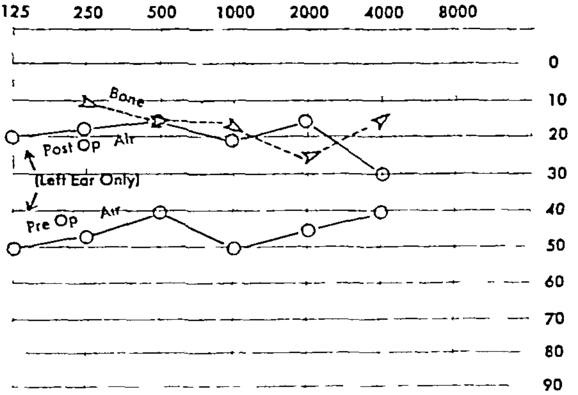
Figure 29

Figure 28

Photograph of a left middle ear displayed for the purpose of showing variations in the round window

This is a view of two round windows which have no niche and are apparently completely separate Membranes are thought to be present in both The small superior window faces upward and laterally, whereas the inferior window faces posteriorly and inferiorly

A large avascular promontory may be contrasted to Figure 31



Pre-operative and Post-operative
Audiogram of patient shown in Fig 5.

Figure 29

Photograph of a left middle ear displayed for the purpose of showing variations of the round window

A large round window niche is seen in this ear and multiple rough projecting bony spines are seen inferiorly These are frequently seen in the hypotympanum

The large round window membrane is clearly seen covering the fluid of the labyrinth The membrane is facing laterally, inferiorly, and posteriorly This position on the posterior inferior aspect of the promontory is the usual position for the round window

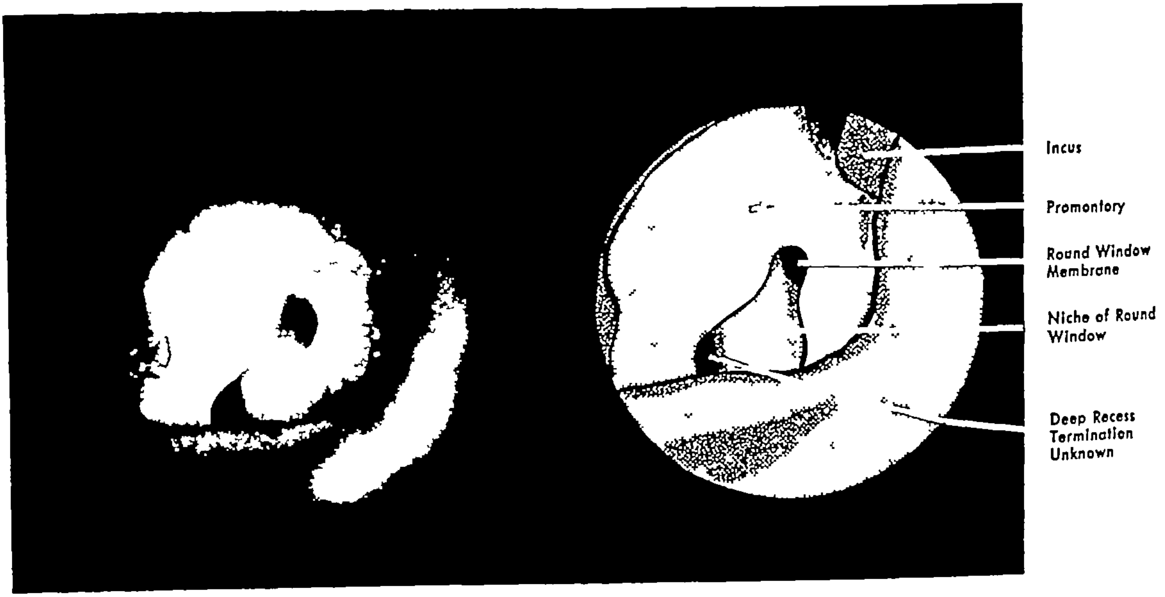


Figure 30

Figure 31

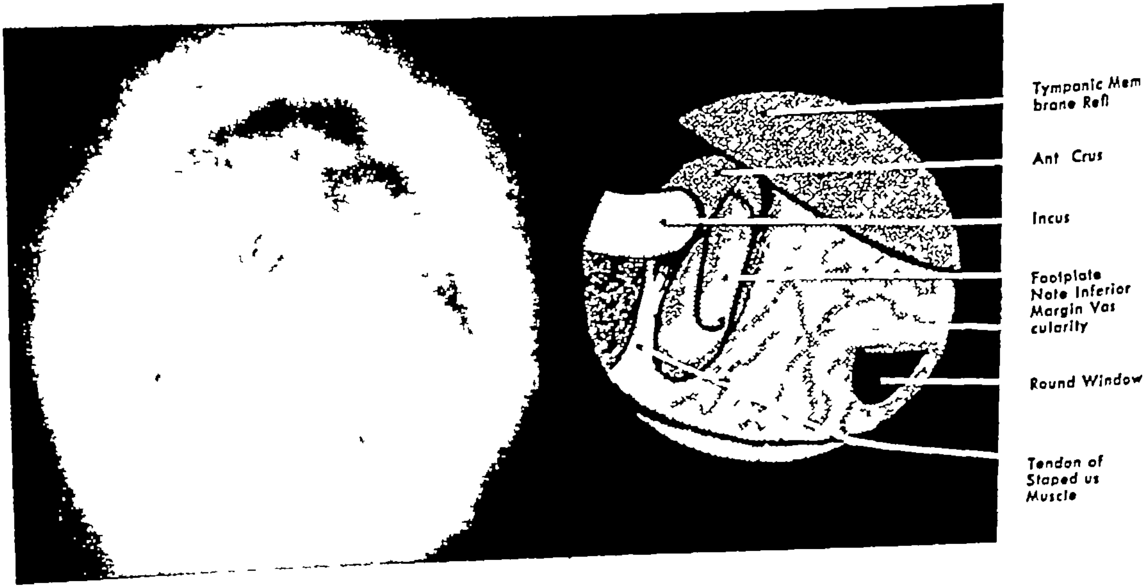
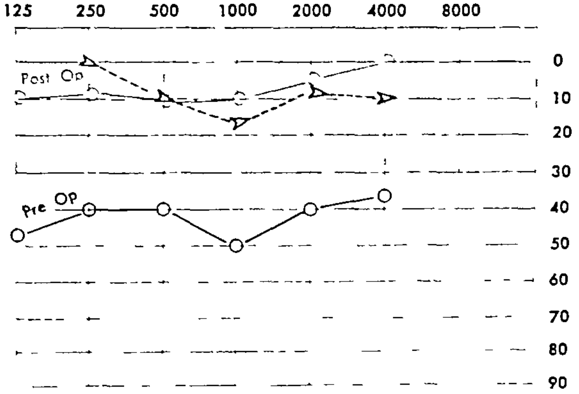

Tympanic Membrane Refl
Ant Crus
Incus
Footplate Note Inferior Margin Vascularity
Round Window
Tendon of Stapedius Muscle

Figure 30

Photograph of a left middle ear displayed for the purpose of showing variations in the round window

This could be called the double-barreled round window The upper window has a definite membrane which is extremely small and faces inferiorly and slightly laterally The lower window may, or may not, have a definite labyrinthine connection with a separating membrane These two depressions are located in a well defined niche which does not merge into the hypotympanic recess inferiorly as was seen in Figure 29



Pre-operative and Post-operative Audiograms of patient shown in Fig 6.

Figure 31

Photograph of a right middle ear displayed for the purpose of showing variations in the round window, the stapedius tendon, the stapes, and vascularity

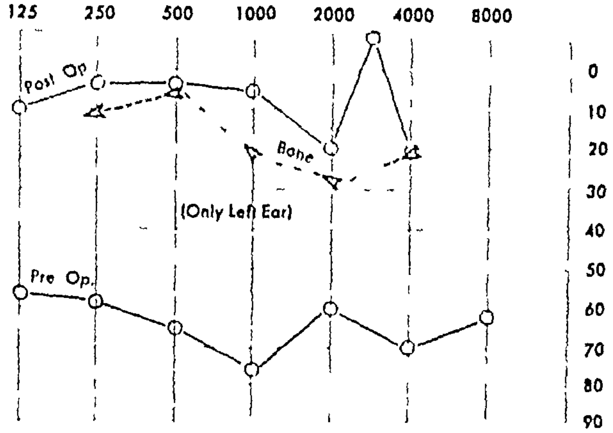
This is a very large round window and is situated in the usual promontory position but is without a niche The membrane of this window is facing mostly in a lateral direction and is unusually superficial

The stapedius tendon is quite long and is attached directly to the head of the stapes It is well seen in its entirety, including the pyramidal eminence This is unusual unless a portion of the external bony canal wall has been first removed The stapedius tendon is also directed slightly superiorly This is not too unusual, but is still in its most infrequent position

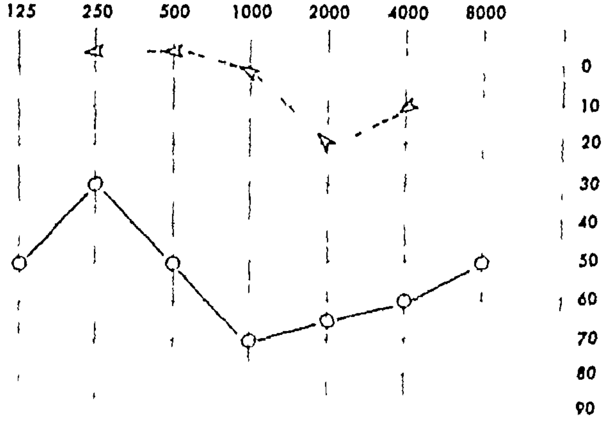
The stapes is located in a very shallow niche and its crura are turned slightly inferiorly An unusual view of the entire stapes is seen The crura are unusual in that they are approximately the same length and are similarly arched A rare view of the entire lower margin of the footplate is seen

The incus articulates with the head of the stapes in the more infrequent posterior position

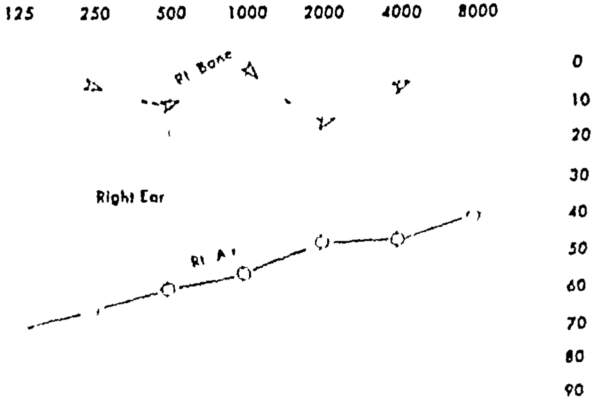
More vascularity than usual is present in this ear The amount of vascularity is extremely variable and this ear does not represent the most extreme vascularity that may be seen Note the large number of vessels over the promontory and the blood-filled appearance of the crura This may be compared to Figure 30



Pre-operative and Post-operative
Audiograms of patient shown in Figs 9 10, 11



Audiogram of patient shown in Figs 13 and 14



Audiogram of patient shown in Fig 15

observed in numerous places in the bony orifice of the round window (see Figs 29, 22) In a majority of patients, what appeared to be residual strands of mesenchymal tissue formed bizarre patterns over the window (see Fig 29)

The usual round window could be seen easily immediately upon opening the middle ear in about the 8 or 9 o'clock position and on the inferior posterior slope of the promontory (see Fig 26) The round window membrane is usually seen clearly, and is facing posteriorly, inferiorly and laterally It is seen to move with good amplitude on normal footplate motion The round window may be seen high up on the promontory in a very anterior position, with the membrane facing in a superior, posterior, and lateral direction (see Fig 27), or it may be seen located far posteriorly so that it is almost entirely hidden by the external canal wall (see Fig 20) An inferior 7 o'clock position is also possible

The round window usually is located in the superior anterior end of a wide, long, excavated bony niche (see Fig 26) This niche usually is roughly bean-shaped and may have bony projections or spines in the lower end (see Fig 29) This may be continuous, with the same rough bony topography frequently seen in the hypotympanum The lower end of this niche may, on the other hand, be smooth and present another rounded depression, or tunnel, which gives the appearance of being a second round window (see Fig 30) Dissection to find the termination of some of these so-called double windows has not been possible, but this finding is frequent enough that postmortem investigation may soon give further light

Many ears are seen in which there is no niche for the round window (see Fig 28) The labyrinth tunnel orifice ends without elaboration on the promontory in a variety of positions as described above The true round window membrane almost invariably, however, is recessed a short distance in this tunnel Superficial tympanic mucous membrane may bridge over the exterior of the orifice, but investigation usually reveals that this is a pseudo round window membrane, and the true round window membrane will be found in a deeper position

EMBRYOLOGIC DISCUSSION OF FIGURES 7 AND 8

The stapes is derived from the second visceral (branchial) arch, and even after differentiation is well under way (16 mm. stage), the head of the stapes is still attached to the original branchial arch. This remaining connection eventually attaches to the otic capsule and becomes the pyramidal eminence and the stapedius muscle and tendon. One would assume that premature separation of the stapes from the second visceral arch occurred in this ear, therefore, total absence of the muscle is observed and no trace of its origin or insertion can be found.

The malleus and incus are derived from the first branchial arch and appear first at the 13 mm. stage as one mass. By the 25 mm. stage, the malleus and incus are easily identified and are separated by a distinct incudomalleolar joint. It is about this time that the long process of the incus gradually nears and finally joins the head of the stapes in an articulation. The triple bony union, seen in Fig. 8, represents disturbed differentiation during this development. Since the connection of the head of the stapes, with its second visceral arch, detaches and joins the otic capsule to become the stapedius muscle, one might expect it occasionally to be misdirected and to join the handle of the malleus. This would explain the triple bony union seen, but this explanation would also require that tissue differentiation be directed into bone instead of muscle.

Improper development of the first branchial arch in the formation of the malleus and incus is another possibility. These two bones are at first one mass and it is conceivable that an isolated area in the region of the long process of the incus and the handle of the malleus might remain fused and eventually unite with the stapes.

The normal attraction of the stapes head for the incus might also be duplicated in the handle of the malleus, therefore, all three might fuse together in a triple union. The lack of articulating surfaces could be the result of immaturity

EMBRYOLOGY

The malformations seen in Figs 13, 14, 15, and 16 are difficult to explain embryologically, due to the very thin fragile crura of the stapes The immature stapes normally is large and bulky All of the other variations would be explained by growth distortion beginning during the eighth to the twelfth embryonic week By this time, the union of the incus and stapes has occurred, the stapedius muscle is attached, and the footplate of the stapes is beginning to be blended with the lamina stapedialis of the otic capsule The process has not been completed in these patients, and the annular ligament has not differentiated to produce the oval window As a result there is solid otic capsular bone throughout the region of the oval window in these ears

DIAGNOSIS

In all the cases specifically discussed in this thesis the external canals and tympanic membranes were normal The consideration of diagnosis is then in this light One may, however, suspect a malformation of the middle ear in some patients prior to operation The following observations may suggest middle ear anomalies *1* Cases of unilateral conductive deafness seem to have a higher percentage of abnormalities *2* Conductive deafness observed since birth or early childhood, either bilateral or unilateral, should suggest the possibility of middle ear abnormalities even in the presence of a normal tympanic membrane Conductive deafness of this type is greater than that which would be due to any other acquired pathologic process [-3] *3* The absence of Carhart's notch in the bone conduction curve may be of diagnostic significance [-3] A 50 to 65 db air conduction loss is present in most patients, and both the air and bone conduction curves present a typical flat audiogram through speech frequencies [-3] In the patients reported here, Carhart's notch was present often, but the characteristic flatness of the air conduction curve was observed in every case *4* Congenital deformities of the middle ear should be anticipated if the patient demonstrates *other anomalies* *This is particularly true of* deformities of the branchial arch derivatures *5* History dat-

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In many instances, there will be no warning of significant variation or abnormality of the middle ear even after careful history, physical examination and audiologic tests have been employed. The use of a highly maneuverable operating microscope with direct lighting and magnification up to 40 diameters is necessary to study these interesting structural variations. One must be able to change both the position of the patient's head and the direction of vision through the microscope in order not to overlook the unusual changes in these minute structures. Insistence upon good binocular visualization and a routine of systematic inspection prepares the mind to attempt a rational surgical maneuver which will be best designed to fit the need.

ETIOLOGY

The word variation is used here in the sense that it is an all-inclusive term indicating any deviation from normal. It, then, includes a vast variety of conditions. In this sense, variations seen in the middle ear may be either congenital or acquired in origin.

CONGENITAL DEFORMITIES

Congenital deformities may be due to disturbed embryologic development on the basis of hereditary defects. Examples of this are the Treacher-Collins[164] syndrome, or severe varieties of otocephaly[7, 68, 133, 169] These cases do not fall in the group of isolated middle ear defects.[7] These malformations usually involve several of the branchial derivatives.[7] In all of the available literature I could find no single case of middle ear deformity without other accompanying deformities in which there was a definite family history; furthermore, in the cases reported in this thesis, there were no histories of similar conditions being present in other members of the family. In any of the more major deformities seen in the middle ear which do not have an obvious origin, we must logically, however, consider heredity to be a strong etiologic possibility.

Congenital deformities may be due to intra-uterine fetal injuries. Deformities in certain cases have been ascribed to maternal viral disease, such as mumps, rubella[139] and poliomyelitis.[138, 61, 83] Fetal position in utero has been considered to be a factor in the production of congenital deformities. One investigator reported changes in the inner ear and central nervous system in the newborn with abnormal fetal positions.[110] He examined six patients with abnormal position and five of the six had histologic changes. In two, changes were found in the inner ear, and in one there was a severe disturbance in the development of the inner ear and middle ear. Collaboration of investigators with obstetricians might in the future shed light on this suggestion. All of the cases found in the literature in the above categories had multiple defects outside the middle ear. None of the cases reported in this thesis have known accompanying deformities outside the middle ear, and none of the conditions reported here could be traced directly to intra-uterine injury as a possible etiologic factor.

Variations in the middle ear may be produced by congenital deformities due to alteration of developmental processes by a variety of unknown causes before birth. The vast majority of variations have no obvious cause. Tardy or delayed resorption of mesenchyme in the middle ear has been considered to be due to hormonal or enzymatic imbalance.[63] If hormonal and enzymatic factors are effective in altering the resorption of this tissue, it is reasonable to assume that these factors might affect other developmental processes. Diabetes,[82] radiation,[81] dietary deficiencies, incompatible blood types[84] (RH factors), eclampsias, maternal and fetal hypoxia,[85] and excessive use of drugs might conceivably produce changes in the normal pattern of development. An unusually high incidence of abnormalities of the ear occurs in persons born prematurely. The conditions listed above are only presumptive possibilities, and thus far there has not been a well documented case reported in which these factors have been proven to cause isolated middle ear malformations.

osteogenesis, or osteoporosis, making possible the formation of bony projections and bridges which could fix the ossicle in place It was thus suggested that irritation produced by vibratory activity in areas where bone is in contact with bone could be a stimulus promoting the formation of bony bridges It has been my frequent observation that most stapedial crura rest against the promontory to some degree These, with few exceptions, have no bony fusion, and yet the structures are so much in contact developmentally that the mucous membrane seems to make no attempt to grow between them, but rather appears to surround in certain areas the individual crus and the promontory as one unit This proximity may remain for a lifetime without bony union These facts cast considerable doubt on the theory of vibratory activity producing bony bridges Reports of ossification of the stapedius tendon causing stapedial fixation have been made[143] Bony bands extending from the promontory, or facial ridge, to the crus of the stapes, thus producing stapedial fixation, have been reported[52] Vibrations and inflammatory irritations have been suggested as possible etiologic factors[52 97] Attention has also been directed to the posibility of bony bridges (not otosclerotic) which could, in places, cross the annular ligament The lack of proper differentiation from chondral tissue into a fibrous ligament could be responsible for stapes fixation in these ears In this event, the primitive chondral tissue would develop into bone

Infection with its pathologic sequelae is well known in the middle ear, and will be discussed only briefly in the light of these observations Among the 500 cases considered in this thesis, there was an unusual lack of adhesions observed in the middle ear, even though a frequent history of childhood earaches and suppuration was obtained This was an unexpected finding and points up the fantastic ability of the living cell to restore order out of chaos and purpose out of destruction This ability may, however, serve to blind the otologist The tympanic membrane may return to normal appearance and, in a few isolated cases, lead one to believe that all suppurative disease in the middle ear has also been resolved without an aftermath of scar tissue In these cases, one may lift the tympanic membrane only to uncover an extensive network of thick scar bands True, scar bands should not be confused with the tiny strands of unresolved mesenchymal tissue which are so frequently seen around the malleus, the incus, and especially in the region of the stapes[63] These strands are present to some degree in the majority of middle ears and apparently hamper sound transmission very little (see Fig 20) In cases of delayed, or incomplete, development, this tissue may be much more in evidence (see Fig 13)

Atrophy and necrosis of bone, possibly due to infection, can be suspected in certain cases such as Fig 21 Presumption that infection can produce such change is based upon the frequently seen erosion of the ossicles in chronic mastoiditis and chronic otitis media The lenticular process of the incus seems to be a particularly vulnerable area of osteolytic attack The total erosion of this end of the long process produces a separation of the incus from the stapes and results in a conductive deafness due to interruption of the ossicular chain Isolated erosion, or atrophy, of this process separate from any other bony involvement is difficult to understand Why the head of the stapes and the crura, or the malleolar head is not also eroded by the same pathologic process, is a valid query Perhaps it is because the long process of the incus projects a greater distance from any base source of soft tissue blood supply than any part of the other ossicles They may be the most vulnerable portion for inflammatory destruction It thus may become the first part involved and, if the pathologic process is controlled, destruction occurs only in this area Perhaps this deformity is common and is only now being seen

Otosclerotic bone in this series could be seen in the great majority of cases Foci of otosclerotic bone usually were seen near the anterior end of the footplate of the stapes The amount of bony overgrowth varied from that which was barely distinguishable to large mounds which enveloped the base of the anterior crus of the stapes Fairly frequently, otosclerotic bone was seen covering a portion of the footplate, or even infiltrating and distorting it in its entirety Occasionally, the surrounding bony capsule of the labyrinth, the annular ligament, and the entire footplate could be seen to be osteogenesis, or osteoporosis, making possible the formation of bony projections and bridges which could fix the ossicle in place It was thus suggested that irritation produced by vibratory activity in areas where bone is in contact with bone could be a stimulus promoting the formation of bony bridges It has been my frequent observation that most stapedial crura rest against the promontory to some degree These, with few exceptions, have no bony fusion, and yet the structures are so much in contact developmentally that the mucous membrane seems to make no attempt to grow between them, but rather appears to surround in certain areas the individual crus and the promontory as one unit This proximity may remain for a lifetime without bony union These facts cast considerable doubt on the theory of vibratory activity producing bony bridges Reports of ossification of the stapedius tendon causing stapedial fixation have been made[143] Bony bands extending from the promontory, or facial ridge, to the crus of the stapes, thus producing stapedial fixation, have been reported[52] Vibrations and inflammatory irritations have been suggested as possible etiologic factors[52,97] Attention has also been directed to the posibility of bony bridges (not otosclerotic) which could, in places, cross the annular ligament The lack of proper differentiation from chondral tissue into a fibrous ligament could be responsible for stapes fixation in these ears In this event, the primitive chondral tissue would develop into bone

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completely overrun by massive invasion of the pathologic process In these cases it was impossible to distinguish the anatomical edge of the footplate, or indeed, to differentiate the footplate from the otic capsule On rare occasion, the otosclerotic bone was seen in such huge mounds that it practically covered both crura and footplate, almost to the point of obliterating the obturator foramen of the stapes (see Fig 19)

Many other diseases, such as diabetes, syphilis, tuberculosis, cholesteatoma, etc, can produce destructive changes in the middle ear None of these was a factor in any of the cases reported in this series

CONCLUSIONS

In the past the discovery of middle ear malformations unassociated with other known defects has been extremely rare A large number of variations and malformations of the middle ear have been observed by me in 500 trans-aural tympanotomies It is reasonable, therefore, to assume that these are not rare

Variations and malformations must be considered in operative procedures of the middle ear, otherwise, a slight distortion or absence of a landmark can produce a mechanical pitfall or an uncharted course for the surgeon

Trans-aural tympanotomy in patients with unexplained deafness of a conductive type is a rational diagnostic, and sometimes corrective, procedure

The study of variations and malformations leads to a better understanding of the physiology of sound conduction, and offers evidence to support or deny certain functional theories

Investigative efforts in embryology, histology, genetics, pathology, and other basic sciences may be stimulated by the observation of malformations and variations in the middle ear

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AMERICAN RHINOLOGIC SOCIETY

The Annual Program Meeting of the American Rhinologic Society will be held at the Palmer House, Chicago, on Friday, October 17, and Saturday, October 18, 1958 The speakers will include Ralph Riggs, M D, "Maxillary and Pre-Maxillary Approach to Septal Surgery", Jules Masserman, M D, "Relationship of Olfactory Factors in Neurosis in Animals" A paper on the "Physiology of Respiration" will be presented by David Cugell, M D, "Heat and Moisture Exchange of the Respiratory Mucous Membrane," by Irving Cramer, M D, "Second Golden Decade of Rhinologic Surgery—The Advances of the Past Ten Years," by Harvey Gunderson, M D A discussion entitled "Concepts of Nasal Physiology as Related to Corrective Nasal Surgery," by Maurice H Cottle, M D, "Bone Transplants" by Robert Ray, M D

There will be a panel discussion on Hump Removal, Roof Repair and Nasal Process Corrections

The meeting will start at 1 30 p m on October 17 and adjourn at 4 00 p m on Saturday, October 18, 1958 For further details write Robert M Hansen, M D, Secretary, 1735 No Wheeler Ave, Portland 12, Ore

DEVELOPMENTAL ANATOMY OF THE TEMPORAL BONE AND AUDITORY OSSICLES IN RELATION TO SOME PROBLEMS IN ENDAURAL SURGERY *†‡

BARRY J ANSON, Ph D ,
Chicago, Ill
and
THEODORE H BAST, Ph D ,
Madison, Wis

INTRODUCTION

The bones of the human skull are developmentally dissimilar to a striking degree, each apparently following an individualized route to maturity the frontal ossifies from two centers which appear in the eighth fetal week, the zygomatic from a single center, appearing in membrane bone in the second month, the sphenoid from 19 centers, the temporal bone from 14, the first one of which is formed in the fourth month, the last about five weeks later

Most remarkable of all are the auditory ossicles, which are made over for new uses, transformed from branchial to

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*Read at the meeting of the Middle Section American Laryngological Rhinological and Otological Society Chicago Ill Jan 13 1958

†From the Department of Anatomy Northwestern University Medical School and the Department of Anatomy University of Wisconsin (contribution No 629 from the former)

‡Various phases of the inclusive investigation carried out under the auspices of the Central Bureau of Research of the American Otological Society by the present authors and their colleagues at the University of Wisconsin and at Northwestern University Medical School have been reported in the following journals Ann Otol Rhinol and Laryngol 51 343 1942 51 891 1942 53 42 1944 55 467 1946 55 278 1946 56 278 1946 55 700 1946 56 957 1947 57 103 1948 57 603 1948 58 739 1949, 59 1088 1950 60 1072 1951 61 740 1952 62 1084 1954 63 394 1954 64 802 1955 Arch Otolaryngol 10 459 1929 16 19 1932 18 1 1933 18 291 1933 23 509 1936 24 127 1936 27 402 1938 27 588 1938 28 676 1938 29 939 1939, 30 183 1939 30 922 1939 32 771 1940 36 891 1942 37 650 1948 52 882 1950 The Laryngoscope 56 561 1946 66 785 1956 Quart. Bull Northwestern Univ Med School 14 250 1940 14 258 1940 15 263 1944 18 33 1944 23 465 1949 25 96 1951 25 366 1951 26 344 1952 28 17 1954 29 21 1955 30 235 1956 30 331 1956 Contributions to Embryology Carnegie Institution 21 53 1930 Anat. Rec. 48 141 1931 59 15 1934 65 485 1936 99 55 1947 106 361 1950 Proceedings of the School of Public Health University of Michigan (Inservice Training Course The Acoustical Spectrum) Feb 1952

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acoustic function Quite as extraordinary as the way in which the separate elements of the auditory apparatus originate, grow and attain maturity, is the independence enjoyed by each as it follows a developmental course that finally leads to interdependent adulthood Time tables here are as different from one another as the developmental history and adult condition of the parts when compared with corresponding features in the morphogenesis of a typical long bone

OBSERVATIONS AND DISCUSSION

1 *Otic Capsule*

In the human embryo of five weeks (8 mm), the auditory apparatus is represented merely by an epithelial vesicle which has lately been freed from the parental ectodermal layer (the future integument)

The surrounding mesenchyma is undifferentiated, there being as yet no histological prediction of change into precartilage for an otic capsule, however, no sooner has precartilage formed an encapsulating investment than deorganization of the newly-formed tissue begins around the parts of the endolymphatic (otic) labyrinth A reticulum becomes vacuolated, then the vacuoles coalesce to produce the communicating spaces of the perilymphatic (periotic) labyrinth These changes take place in a six-week period (between the fifth and the eleventh week)

In the fetus of nine weeks (40 mm), both the otic (endolymphatic) and periotic (perilymphatic) labyrinth of the internal ear are formed, the otic capsule is a cartilaginous envelope for the labyrinthine ducts and surrounding canals and scalae In the area of the future middle ear, the ossicles are formed in cartilage and lodged in mesenchyma Growth in cartilage then continues through another period of six weeks

The otic capsule of a fetus in the fifth fetal month (19½ weeks, 160 mm) already displays distinguishing features in the cochlear and canalicular divisions in the cochlear portion, ossification has been initiated, in the canalicular part, cartilage is not yet being replaced by bone, rather, it is being destroyed, rendered spongious to permit terminal increase in the arcs of the semicircular ducts

The buds of vascular tissue that destroy the cartilage enter through the subarcuate fossa, which at this stage is a relatively ample excavation

The first ossification center appears in the otic capsule at the age of about 16 weeks (115 to 120 mm), the last (14th) at the end of the fifth month

As soon as an ossification center is definitive, it is found to consist of three layers, each of which has its own rate of increment and maturation, and time of appearance in the cochlear and canalicular divisions of the capsule

The inner periosteal (or endosteal) layer already forms a thin parietal shell for the turns of the cochlea, it is completed *quickly but remains virtually unaltered throughout life*

An outer periosteal layer appears at the same time Immediately other laminae are added externally—in steady acquisition, and after the regular pattern existing in the cambium layer of the periosteum in a typical long bone, however, the structure differs therefrom in that, despite growth, the simple laminated bone is never replaced by bone of Haversian type

The middle layer, unlike the other two, is compound it consists of a *calcified cartilage matrix in* whose lacunae invading osteoblasts have surrounded themselves with bone which, while *formed in membrane,* is deposited upon the framework offered by the calcified cartilage This combination is intrachondrial bone The intrachondrial tissue is formed concurrently with the outer layers of the ossification center, but production of the endochondral bone is delayed until the early weeks of postnatal life, at which stage it is produced with sweeping rapidity

The layers of the capsule are especially distinct in the fetus at midterm, *i e ,* in a specimen of 21 weeks (183 mm) in the

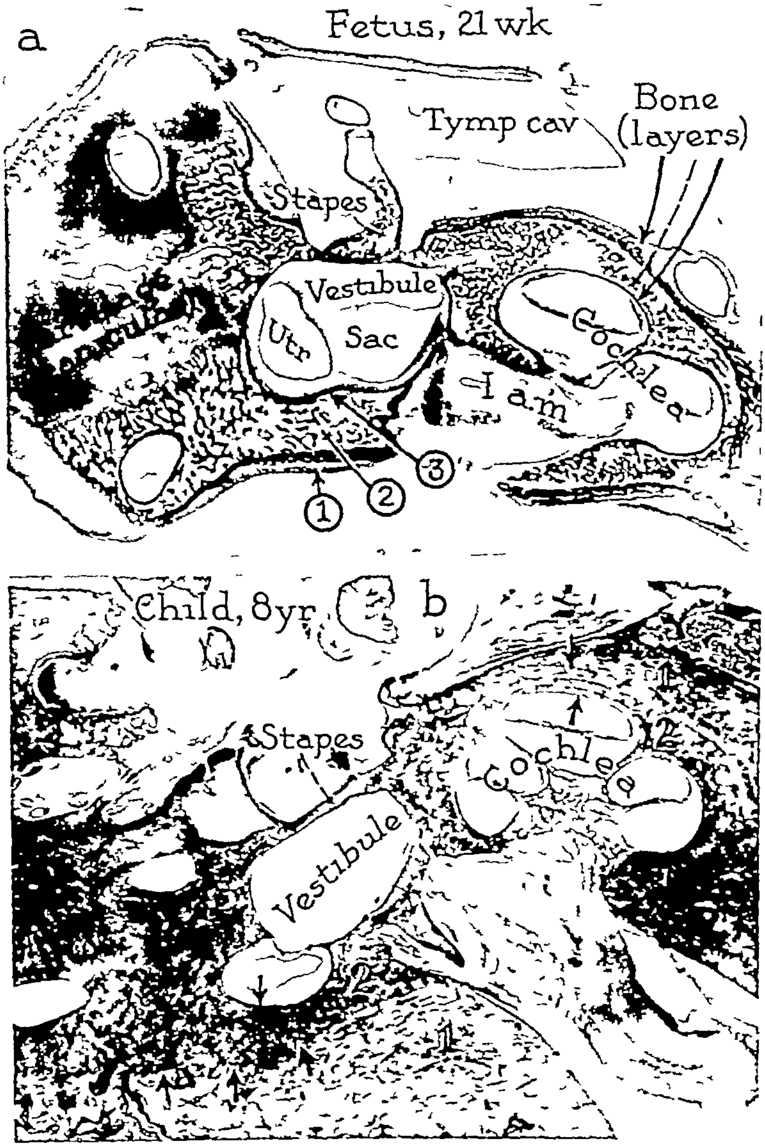

Fig 1 Stages in the development of the otic capsule Wisconsin series 21 and P37 a.—Fetus of 21 weeks (183 mm) b—Child 8 years old

Abbreviations I a.m internal acoustic meatus Sac saccule Tymp cav tympanic cavity Utr utricle

Numerals indicate the layers of capsular bone In the cochlear part of Fig 1-a (to the reader s right) the downward-directed arrow points to the external limit of the middle layer the upward-directed arrow to the internal (free) margin of the inner layer of bone In the vestibular and canalicular divisions of the same figure (to the reader s left) the single arrow touches the internal margin of the inner layer the three arrows point to the line of meeting of the outer and middle strata of bone cochlear, vestibular and canalicular portions of the capsule (see Fig 1-a)

These layers retain their fetal appearance, even in areas where the capsule is being rebuilt The tympanic wall of the lateral semicircular canal (the site of fenestration surgery) is one such area, and the external aperture of the vestibular aqueduct is another

In a 38-week (350-mm) fetus, cartilage persists in only two locations, *i e*, in the wall of the fissula ante fenestram and, continuous therewith, as a rim for the vestibular (oval) window The outer (periosteal) layer has undergone considerable thickening, like the bone of the other two layers, it is non-Haversian and permanent In the middle layer, the cartilage islands are covered by endochondral bone—marrow spaces being correspondingly reduced in bulk In portions of the cochlear capsule, space is still a prominent feature, its existence serves to set off the outer from the inner layer The inner layer is unchanged

In the newborn infant the otic capsule is still cancellous in texture This appearance is due to the histological structure of the middle layer, which is still composed mainly of intrachondrial bone Because of its open texture, the layer is clearly distinguishable from the other two, the inner being relatively thin and smooth-surfaced The outer layer will undergo steady increment until the temporal bone has attained adult form and dimensions The middle layer will assume a petrous consistency as a result of the production of new bone (deposited upon the intrachondrial spicules) The inner layer will remain virtually unchanged throughout life

In the ear of a child eight years of age, the three fundamental layers of the otic capsule are still distinguishable (see Fig 1-b) The chief postnatal changes are two in number increase in thickness of the outer layer , attainment of compact character by the middle layer Frequently a large part of the middle layer will have been destroyed to make way for air cells It has been established that pneumatization may be complete in the young child, and that in some individuals the process is under way in the late fetus

2 *Auditory Ossicles*

The structure of the stapes calls for special discussion in relation to problems presented to the surgeon in the operation for mobilization Developmental history fully accounts for its architectural weakness

In the fetus of 20 weeks (167 mm) the single ossification center has made its appearance on the obturator wall in the area of continuity of the crus with the base

At a slightly later stage (21 weeks, 190 mm), an osseous shell is circumferential for the crus, otherwise, the ossicle remains cartilaginous In the crural portion of the stapes, marrow has replaced cartilage

In the 23-week (202-mm) fetus, ossification has advanced to include the neck of the stapes, and to spread along the crura toward the head of the ossicle Cartilage remains at the basal extremity, but is eroded internally, on the internal surface, endochondral bone is forming

The stapes in the fetus of 24 weeks (215 mm) is composed of bone, except at the extremities Medially, cartilage covers the vestibular surface and the fenestral margin, whereas laterally the primordial cartilage of the capital end persists as an articular plate (at the incudostapedial joint)

The stapes of the 32-week (290-mm) fetus has attained adult form and structure It is completely invested by mucous membrane, both the basal and capital extremities are bilaminar (each of the layers being thin but complete)

All of the structural features which characterized the stapes in the late fetus and in the newborn infant are retained in virtually unaltered form in the adult the ossicle is excessively thin, its base, like the head, is two-layered (the cartilaginous lamina of the vestibular surface investing the endochondral lamina of the tympanic aspect) , mucous membrane not only covers the outer surface of the periosteal bone of the crura and head, but also coats the inner surface of the same layer where, as a result of removal of the obturator wall of the ossicle, the mucosal tunic comes to replace marrow

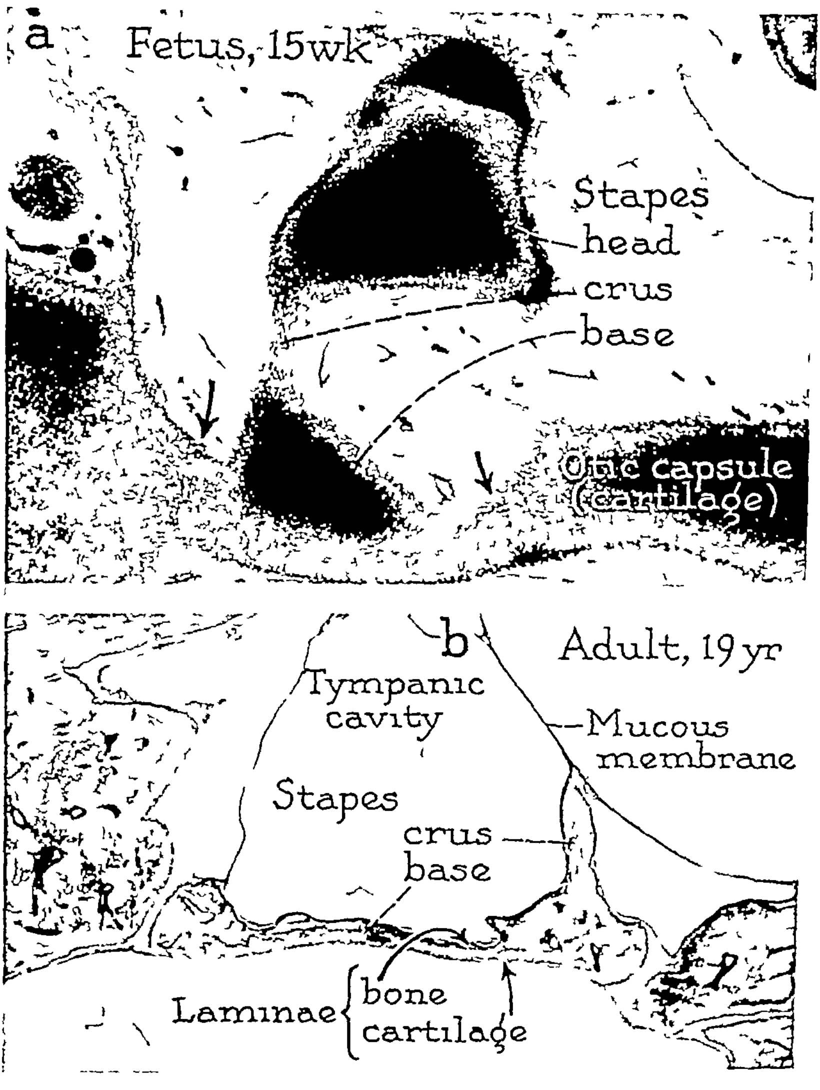

Fig 2 Stages in the development of the stapes Wis 50 and P29
a —Fetus of 15 weeks (111 mm) b —Adult 19 years old

and endochondral spicules The mucous membrane on the base of the stapes lies in contact with the endochondral lamina, which in a process of secondary growth, formed a covering for the persistent cartilage

When once the stapes has been reduced in bulk and strength, it subsequently undergoes negligible alteration The ossicle remains infantile—or, rather, it is already an adult bone in the newborn

By way of contrast, the histological structure of the incus is subject to remodelling at any age in a person's life span (see Figs 3-a and 3-b) , however, in some infantile specimens, excavation of both perichondrial and endochondrial bone may be under way, and in others, destruction is marked, but new bone is being applied to the walls of the recently formed spaces In some adults, erosion may affect chiefly the perichondral layer, in others, secondary excavations appear, as does concurrent formation of tertiary lamination

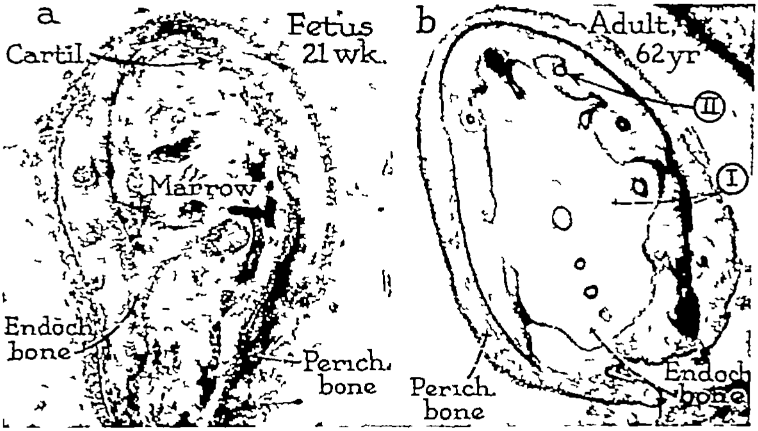

Fig 3 Features in the development and adult remodelling of the incus (long crus) Wis ser 21 and P10 a.—Fetus of 21 weeks (183 mm) b —Adult 62 years old

Abbreviation Cartil cartilage Endoch bone endochondral bone Perich bone perichondral bone Encircled Roman numerals indicate primary (I) and secondary (II) ossification

CONCLUSIONS

The otic capsule is already precartilaginous in the six-week embryo, whereupon the tissue begins to deorganize around the otic labyrinth, predicting periotic vacuolization (for semicircular canals, vestibule and cochlear scalae)

Although bone formation is under way in the cochlear region at 20 weeks, the canalicular division not only remains cartilaginous for a four-week period, but is rendered spongious, permitting expansion of the semicircular ducts Even when capsular ossification is virtually complete, the middle layer still consists mostly of intrachondrial bone Soon after birth, rapid deposition of endochondral bone contributes petrous character to the entire capsule The inner layer never changes, the outer thickens to imbed the capsule

The capsule undergoes late remodelling at the external aperture of the vestibular aqueduct and along the tympanic wall of the lateral semicircular canal, while bone in the canalicular region is being pneumatized

The ossicles, although derived from the branchial skeleton of the embryo, and ossified from a single center each, follow different courses of morphogenesis and at different rates of speed The stapes of the midterm fetus has already attained adult dimensions, but is destined to undergo profound reduction in bulk before birth, after which it remains structurally quiescent Like the otic capsule, the stapes never attains the Haversian stage of typical bone, in that respect it retains lifelong fetal structure The incus, on the contrary, experiences remodelling of both its periosteal and endosteal layers throughout life, yet suffers no grossly discernible loss in bulk

Difficulties which confront the surgeon in employing any one of the several techniques calculated to mobilize an ankylosed stapes are the result of the following circumstances the anatomic position and relations of the stapes, its extreme fragility and its inability to heal, once it has been fractured, the power of the otic capsule to produce rapidly-growing bone in the territory of the vestibular (oval) window All portions of the stapes are fragile, they are already frail in the infant, and will remain so throughout life The crura and base are always thin, the head is pitted or deeply excavated, or both The base (footplate) is usually the weakest part of the ossicle In many cases, bone is a thin lamina on the tympanic aspect, *i e*, toward the middle ear, cartilage, persisting from the fetal stage, completes the base on the vestibular surface

CONGENITAL STAPES FOOTPLATE FIXATION

A Preliminary Report of Twenty-Three Operated Cases [*][†][‡]

HOWARD P HOUSE, M D ,
WILLIAM F HOUSE, M D , (By Invitation),
and
VICTOR H HILDYARD, M D , (By Invitation),
Los Angeles, Calif

INTRODUCTION

Otosclerosis has long been recognized as a cause of fixation of the footplate We now realize there is a second cause, namely, congenital fixation of the stapes footplate This entity does exist, can be diagnosed by clinical means, and can be recognized at the time of surgery [**]

Shambaugh[1] has described five such cases, and Holmgren[2] reported a case of incomplete development of the oval window Altmann[3] has described the histological findings of a case of atresia with congenital footplate fixation Wolff[4] has observed abnormalities in the annular ligament of the new-born

EMBRYOLOGY

Embryologically, the malleus and incus are differentiated from the first branchial arch, or Meckel's cartilage The stapes is derived from the second branchial arch, or Reichert's cartilage Failure to differentiate results in a congenital abnormality of the structures involved, consequently, the stapes and stapes footplate may be involved without involvement of any of the other middle ear structures

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[*] Read at the meeting of the Eastern Section American Laryngological Rhinological and Otological Society Inc. Jan 9 1958

[†] From the Department of Otolaryngology University of Southern California School of Medicine

[‡] Sponsored by the Los Angeles Foundation of Otology

[**] Our gratitude to Eusebio E Llamas M D for his help in the statistical evalaution of these cases

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DIAGNOSTIC FEATURES OF OTOSCLEROSIS IN THE ADULT

The differential diagnosis between otosclerosis and congenital footplate fixation may at times be rather difficult The key to the diagnosis of otosclerosis in the adult is *progression* of the hearing loss If a patient has a slowly *progressive* conductive or mixed type of loss with essentially normal otologic findings, the diagnosis is usually clinical otosclerosis (see Fig 1)

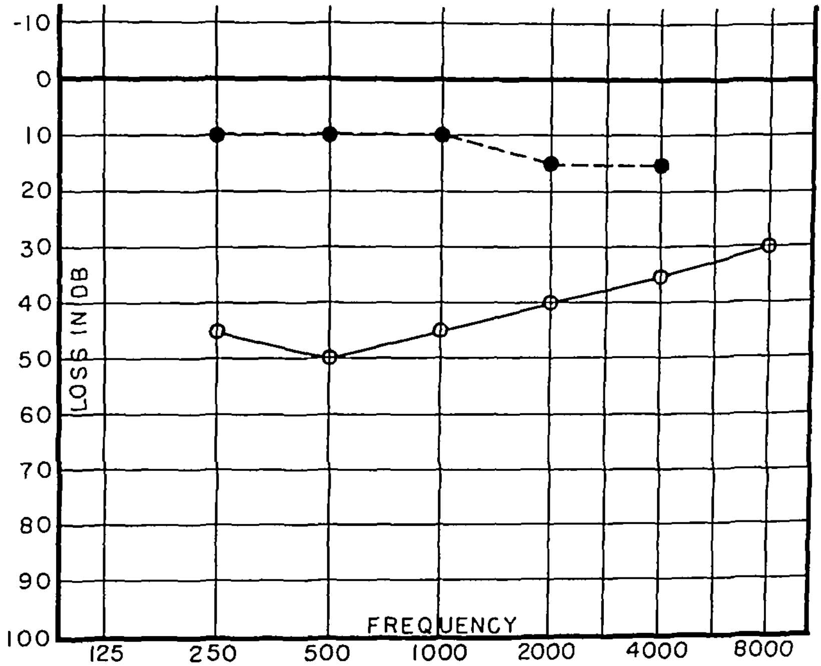


Fig 1 Otosclerosis

The amount of conductive impairment varies with the degree of otosclerotic footplate fixation The air conduction curve usually shows the greatest loss in the lower frequencies Cochlear involvement is quite common and usually involves the higher frequencies

DIAGNOSTIC FEATURES OF CONGENITAL FOOTPLATE FIXATION IN THE ADULT

The key to the diagnosis of congenital footplate fixation in the adult is the *absence of progression* of the hearing loss A patient with a history of a purely conductive *non-progressive* hearing impairment, who has essentially normal otologic findings, may be diagnosed as ossicular discontinuity, or congenital ossicular fixation, occurring usually at the stapes footplate

To determine accurately the *lack of progression* may be very difficult These patients give a history of accidental discovery of the hearing impairment, either by school tests, or as the result of a certain incident that called attention to their hearing deficiency The average age of such discovery in this series of cases was ten years After discovery the patient, and parents, become suddenly aware of the impairment and proceed to test the hearing acuity in various ways As the result one may feel that the hearing is getting worse, when actually the patient is only becoming more aware of the pre-existing deficiency Because of the increased demands made on his hearing, one may feel the hearing loss is becoming greater as he gets older because of his more adult activities

Patients with a congenital fixation of the stapes footplate have grown up with their impairment They automatically compensate for their deficiency, and become excellent lip-readers long before their hearing loss is discovered They frequently give a history of being slow in learning to talk, but all seem to have an excellent speech pattern (see Fig 2)

Audiometric findings in congenital footplate fixation are remarkably constant The air conduction curve is flat and averages 50 db in the three speech frequencies The bone conduction curve also is flat and remains within 10 db of the zero threshold throughout the audiometric frequency range

CONDUCTIVE LOSSES IN CHILDREN

We recently reviewed our patients under 12 years of age who had a conductive loss with essentially normal otologic findings, and who were examined in our office ten or more years ago We found these cases could be classified into four groups

GROUP NO 1

This group consisted of conductive losses of 15 to 35 db in the three speech frequencies, which responded to therapy and had no further difficulty in adulthood

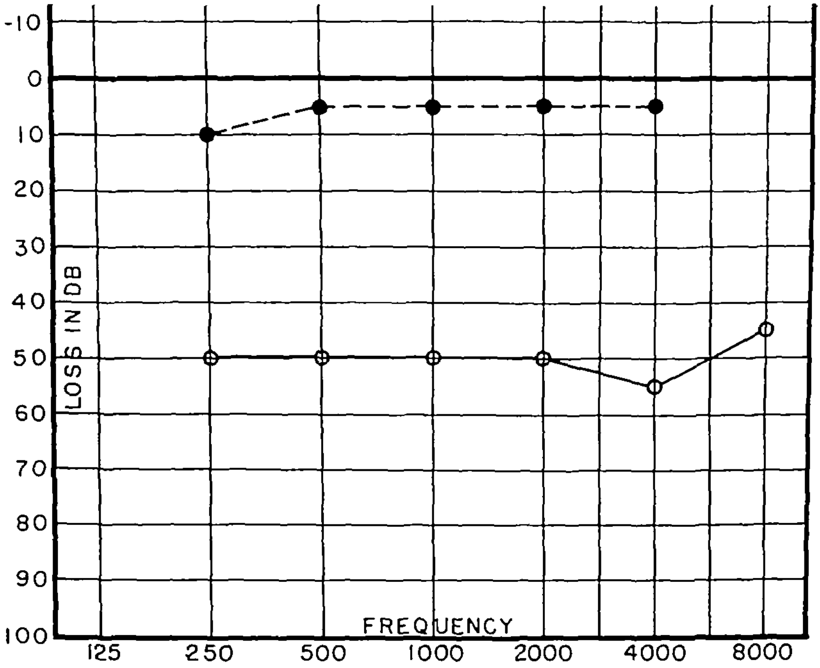
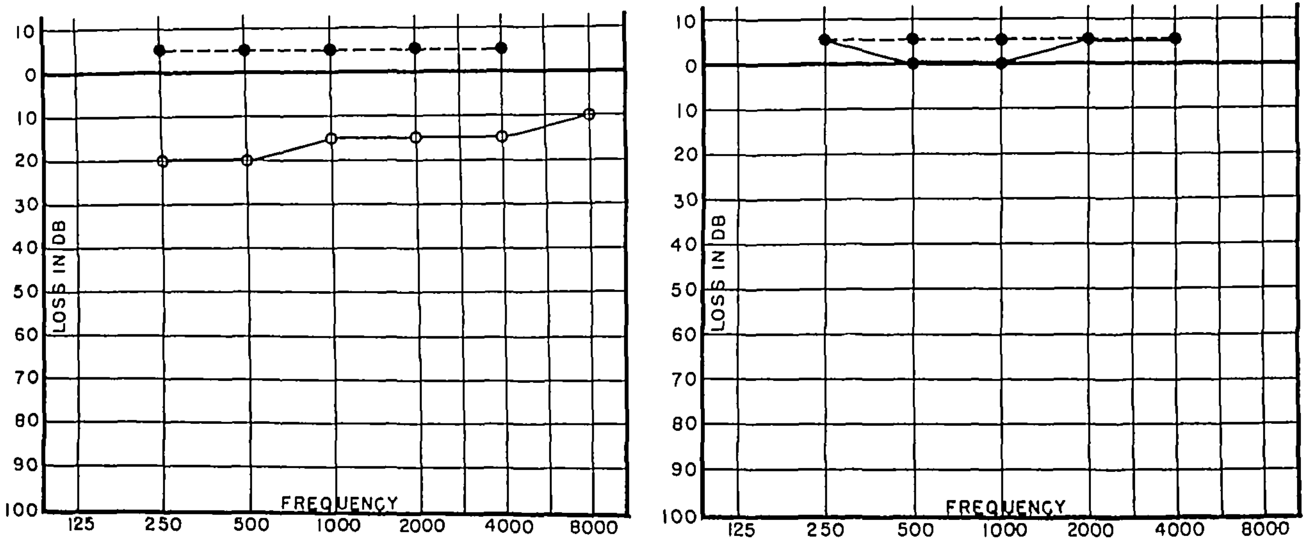


Fig 2 Congenital Footplate Fixation

CASE REPORT

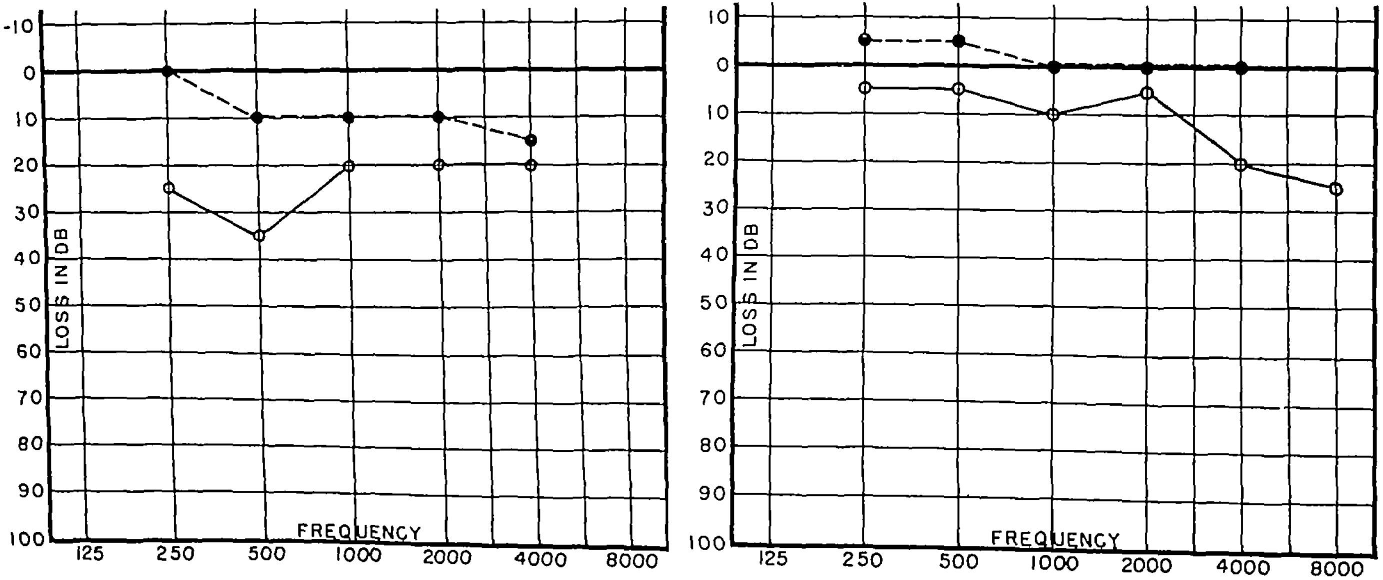
T E age five was first examined in 1945 concerning a hearing impairment which was discovered by routine school audiometry There was no history of middle ear disease and the otologic examination was essentially normal *A tonsillectomy and adenoidectomy was performed* followed by X ray therapy to the nasopharynx The hearing improved following this therapy and has maintained the improvement to date as per the following audiograms (see Figs 3 A, 3 B)



A.

B

Fig 3 A—Age 5 1945 B—Age 17 1957



A

B

Fig 4 A—Age 5 1946 B—Age 16 1957 Spontaneous hearing improvement

GROUP NO 2

This group consisted of children with mild conductive losses of 15 to 35 dbs in the three speech frequencies, who did not respond satisfactorily to therapy in childhood, but later regained their hearing after adolescence This gain was apparently due to spontaneous regression of tubal lymphoid tissue

CASE REPORT

E K age five was first examined in 1946 with a history of repeated upper respiratory infections and recurrent attacks of bilateral acute otitis media with drainage The parents had been aware of a hearing loss for several years

Examination revealed enlarged adenoids and tonsils and their removal was recommended The parents did not desire to have surgery performed, and no therapy was carried out either at that time or subsequently (see Figs 4 A, 4 B)

GROUP NO 3

This group consisted of children with mild conductive losses that increased to loss of serviceable hearing in adulthood, apparently due to otosclerosis Subsequent surgery now being performed on this group is proving the diagnosis of otosclerosis to be correct

CASE REPORT

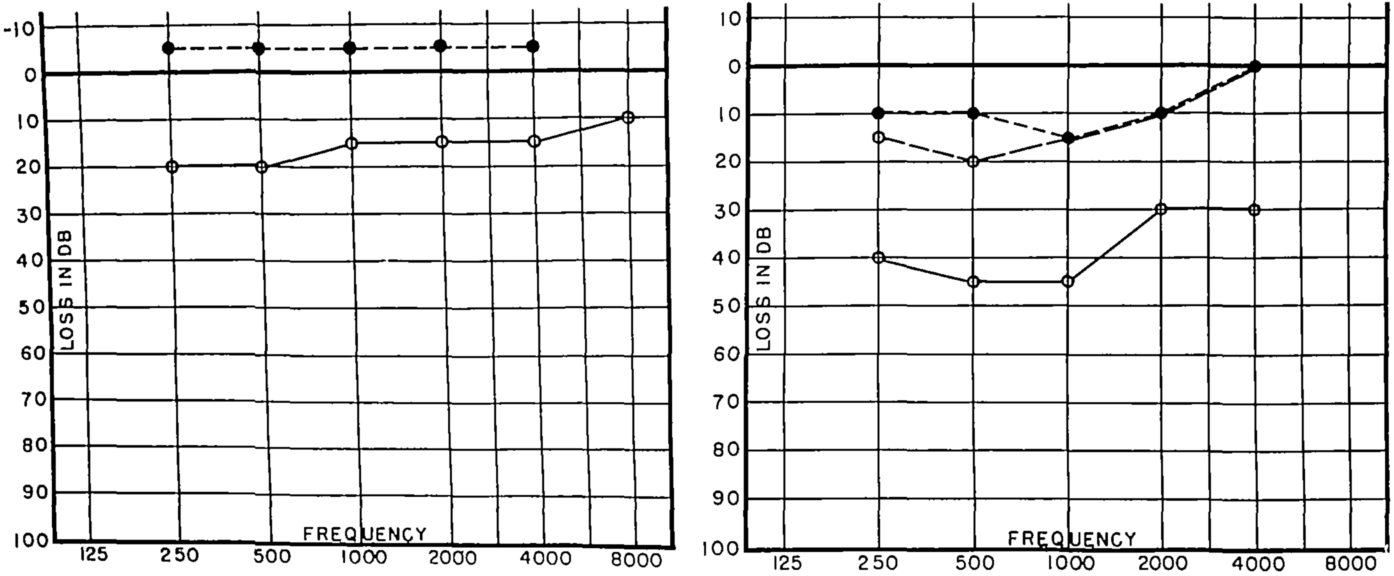
R K age 15 was first examined in 1954 She had noted a bilateral hearing loss for six months which was discovered accidentally and which she stated was not progressive She complained of some tinnitus and stated that she heard better in noisy places There was a positive family history of otosclerosis

Examination revealed essentially normal otologic findings The tonsils and adenoids had been removed at an earlier age and the nasopharynx was free of lymphoid tissue

Two years later another hearing examination was carried out and the hearing loss had progressed considerably during adolescence A mobilization operation was performed at that time with restoration of serviceable hearing as per the following audiograms The findings at surgery were characteristic of otosclerotic fixation (see Figs 5-A 5-B)

GROUP NO 4

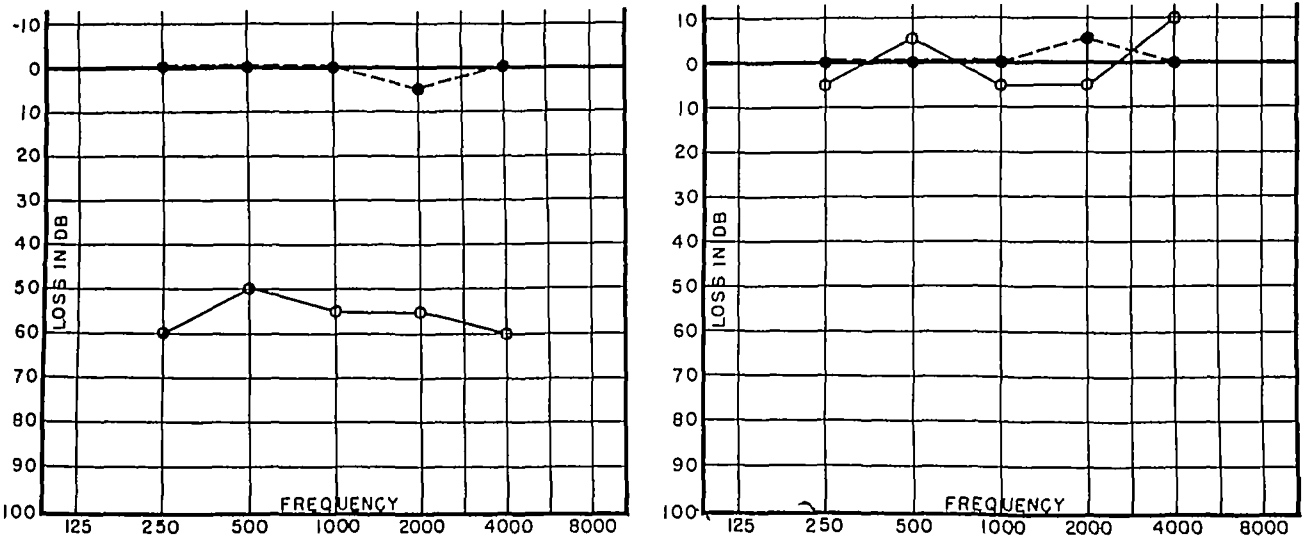
This group consisted of children with a marked conductive loss in childhood, of 45 to 55 dbs, who showed the same degree of loss in adulthood ten or more years later, apparently



A.

B

Fig. 5 A—Age 15 1954 B—Age 18 1957 Note further preoperative loss of hearing to a 40 db average improved following mobilization to a 15 db average Circle-continuous line preoperative circle-line postoperative air conduction solid dots with dashes bone conduction curve



A

B

Fig. 6. A—Aug 10 1956. B—Aug 22 1957. Closure of the bone-air gap following mobilization surgery

due to congenital footplate fixation Subsequent surgery now being performed on this group is proving the diagnosis of congenital footplate fixation to be correct

CASE REPORT

V M, age ten years, was first seen in 1945 The parents stated the hearing impairment was first noted at three years of age, and that the child was rather slow in learning to talk The parents did not notice any progression in the loss and there was no history of ear disease The child was unaware of tinnitus and the family history was negative

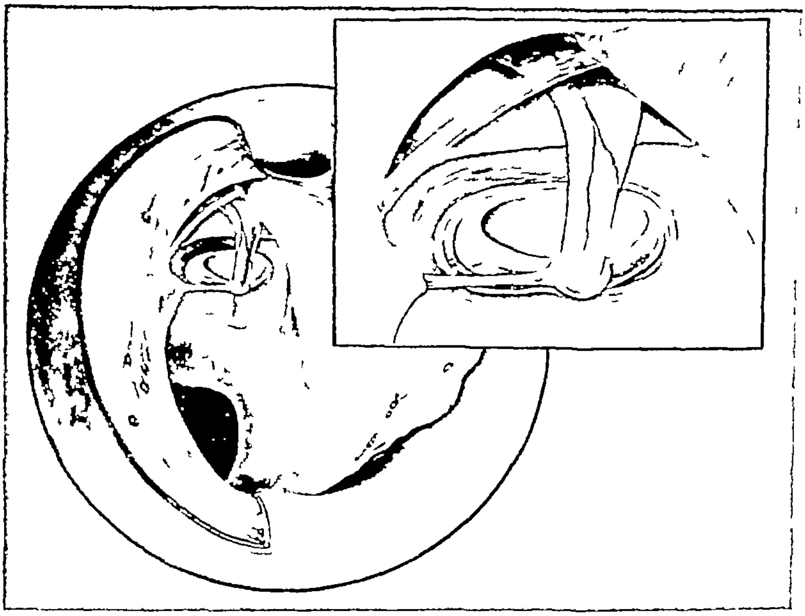


Fig 7 Normal Footplate

Examination was essentially normal except for the audiometric findings which revealed these characteristic audiograms (see Figs 6 A 6 B)

In a child under 15 years of age the diagnosis of otosclerosis is difficult, because the key factor of progression cannot be definitely established The degree of conductive loss at the time of discovery may vary from an average of 15 dbs to 35 dbs in the three speech frequencies, depending upon the degree of otoscelerotic footplate fixation During adolescence progression of hearing loss due to otosclerosis is frequently accelerated rapidly

If a child has normal physical findings, has a conductive loss not to exceed 35 dbs in the three speech frequencies and does not respond to routine therapy, the diagnosis may be clinical otosclerosis Confirmation of this tentative diagnosis can be achieved only by noting further progression of the hearing loss over a period of time, or by surgical exploration and examination of the stapes footplate

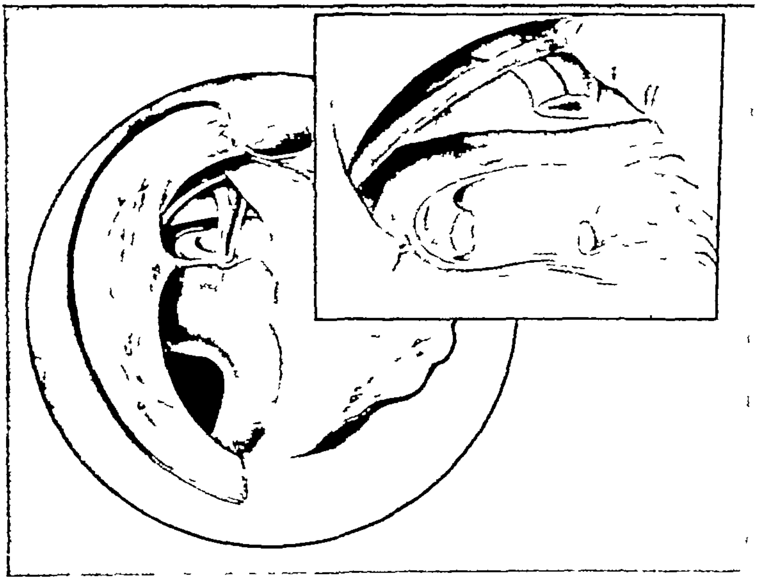


Fig 8 Otosclerotic Footplate

The diagnosis of congenital footplate fixation in the child may also be difficult, due to the lack of a history of progression of the hearing impairment, therefore, the diagnosis of congenital footplate fixation in children is based on normal physical findings and the characteristic flat 50 db pure conductive loss on the audiogram

In view of our long term studies of conductive impairment in children, it seems logical that any child under 15 years of age with a purely conductive hearing impairment approximating 50 dbs has congenital footplate fixation rather than clinical otosclerosis An analysis of our operated cases of congenital footplate fixation in children confirms this hypothesis

OBSERVATIONS AT SURGERY

Surgical exploration by the stapes mobilization approach reveals rather characteristic findings in cases of congenital footplate fixation (see Fig 7)

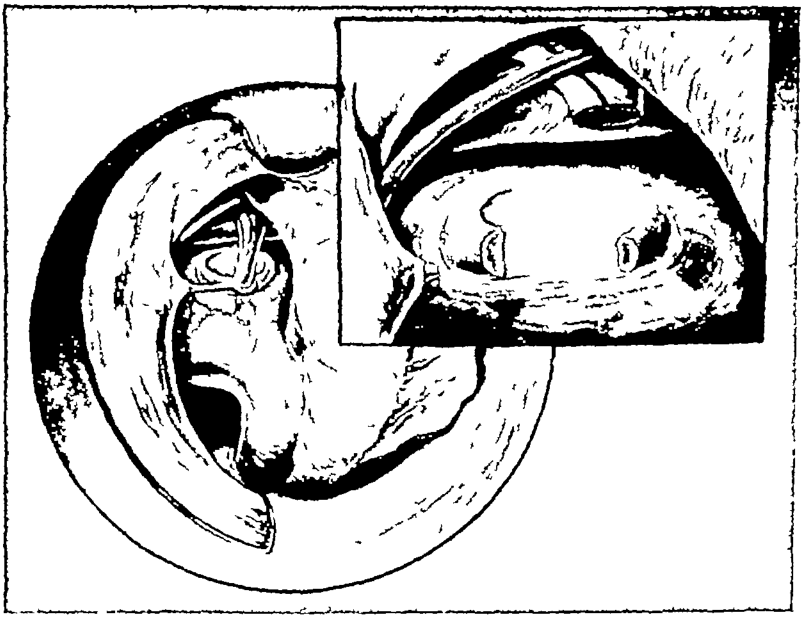


Fig 9 Congenital Footplate Fixation

The normal stapes footplate has a characteristic appearance *There is no increase in vascularity, and the margins* of the footplate and the annular ligament are distinct The central portion of the footplate is thin and usually has a bluish appearance Gentle palpation reveals uniform mobility (see Fig 8)

The otosclerotic footplate has an increased vascularity, usually in the anterior area The margins of the footplate and the annular ligament are difficult to visualize anteriorly, but usually are readily visualized posteriorly The central footplate area is often thin with a bluish discoloration Otosclerotic bone frequently engulfs the anterior crus at its footplate attachment Whitish otosclerotic plaques are often seen spreading over the surrounding bone of the otic capsule Palpation reveals fixation of the footplate, more often in the anterior region (see Fig 9)

In congenital footplate fixation there is no increase in vascularity The central portion of the footplate is not thin, and the bluish discoloration is usually not present The margins of the footplate and the annular ligament are difficult to visualize, since the footplate bone blends into the bone of the surrounding otic capsule This diffuse uniform bony fusion may be thin or thick If thin, the footplate can be readily mobilized, if thick, mobilization cannot be attained by manual pressures Gentle palpation reveals uniform and total fixation of the entire footplate

TABLE I

A Preliminary Report of Twenty Three Operated Cases of Congenital Footplate Fixation

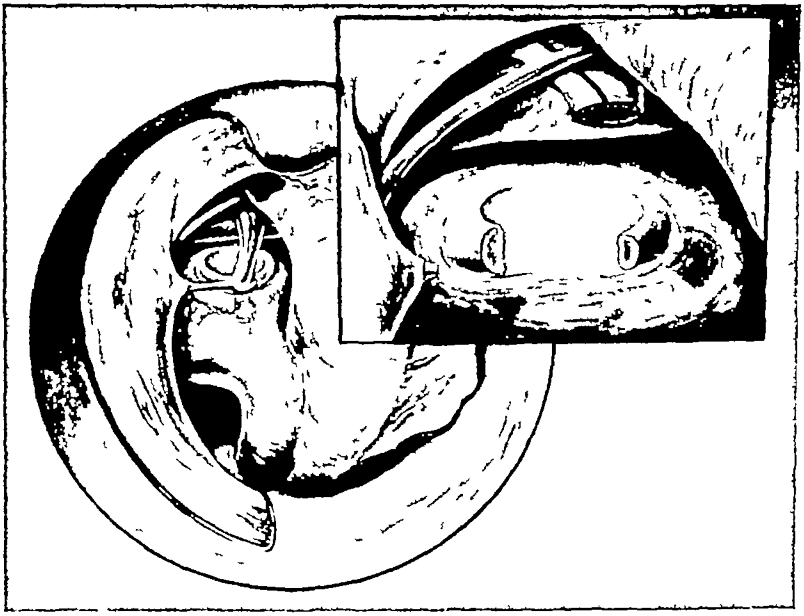
Age of Discovery of Hearing Loss		
Average age	10 years	
Youngest age	2 years	
Oldest age	33 years	
(87% noted hearing loss before 14 years of age)		
Age at the Time of Surgery		
Average age	33 years	
Youngest age	6 years	
Oldest age	60 years	
(Five cases were over 50 years of age)		
Preoperative Air Conduction		
Average loss	50 dbs	Average in the three speech frequencies
Minimum loss	40 dbs	
Maximum loss	65 dbs	

SURGICAL RESULTS

All twenty-three cases were explored by the stapes mobilization approach Mobilization of the stapes footplate was attempted by needle and chisel techniques clinical otosclerosis An analysis of our operated cases of congenital footplate fixation in children confirms this hypothesis

OBSERVATIONS AT SURGERY

Surgical exploration by the stapes mobilization approach reveals rather characteristic findings in cases of congenital footplate fixation (see Fig 7)



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SYMPOSIUM

STAPES MOBILIZATION TWO YEARS LATER

MODERATOR

H P House, M D , Los Angeles, Calif

PANEL

Merle Lawrence, M D , Ann Arbor, Mich
J R Lindsay, M D , Chicago, Ill
Victor Goodhill, M D , Los Angeles, Calif
George E Shambaugh, M D , Chicago, Ill
C M Kos, M D , Iowa City, Ia
E P Fowler, Jr , M D , New York, N Y
P E Meltzer, M D , Boston, Mass

CLOSING REMARKS

Samuel Rosen, M D , New York, N Y
Howard P House, M D , Los Angeles, Calif

OFFICIAL DISCUSSIONS

R J Bellucci, M D , New York, N Y
F A Sooy, M D , San Francisco, Calif
S H Baron, M D , San Francisco, Calif
H F Schuknecht, M D , Detroit, Mich
F R Guilford, M D , Houston, Tex
Joseph Sullivan, M D , Toronto, Canada
Theo E Walsh, M D , St Louis, Mo

OPEN DISCUSSION

Moses Lurie, M D , Boston, Mass
Juergen Tonndorf M D , Iowa City, Ia
Kenneth M Day, M D , Pittsburgh, Pa
Gordon Hoople, M D , Syracuse, N Y
Lee Shahinian, M D , Redwood City, Calif
Howard P House M D , Los Angeles, Calif

Twelve cases (52 per cent) had a significant gain of 11 decibels or more in the three speech frequencies Eleven of these twelve cases reached the 30 decibel level or better three weeks following mobilization Eleven cases (47 per cent) remained essentially unchanged (within 10 decibels of the preoperative level in the three speech frequencies) In five cases (22 per cent) the stapes footplate could not be mobilized by manual means Of these five cases three were subsequently fenestrated and all three reached the serviceable level of 30 dbs or better

This series of cases of congenital footplate fixation is too small, and the time factor too short, to establish conclusions in regard to permanency Cases operated successfully one year ago, however, seem to be maintaining their post-surgical hearing improvement

CONCLUSIONS

1 The diagnosis of congenital footplate fixation is established by observing the characteristic flat audiometric curve by air conduction approximating 50 dbs in the three speech frequencies The hearing loss in these cases is non-progressive

2 Congenital footplate fixation is a definite entity which can be diagnosed clinically and confirmed at surgery

3 Mobilization in cases of congenital footplate fixation is usually more difficult than in cases with otosclerotic fixation If the footplate cannot be mobilized the patient is an ideal candidate for subsequent fenestration surgery

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4 Wolff, Dorothy Personal communication

cause them to vibrate The round window membrane acts as a relief point so the in-and-out vibration of the ossicles can be transmitted through the scala to the round window, which then bulges in and out

There are several things that can happen to prevent this process first, the ossicular chain can be disrupted through the removal of the incus or the disarticulation of the incudostapedial joint A measurement of hearing in this case, an experiment which has been done many times on animals, shows that such a disarticulation gives a loss of around 60 db The reason for this is that we now have a useless drum membrane that is impeding the sound vibration from getting into the inner ear, also, the two windows are in the path of the vibrations that do get through Sound hitting the two windows in phase and with equal intensity will be cancelled out at the sensory cells which lie in the internal path between the windows

If the drum membrane is removed, as has been done both clinically and experimentally, the hearing will improve by about 15 db This leaves a loss of around 45 db, part of which can be accounted for by the cancellation effect of the sound hitting the two windows If, by some means, it were possible to get sound to one window alone, thus preventing the cancelling effect, hearing could be brought up to a 25 to 30 db level This, of course, is quite important because this is in the range of practical hearing—without an ossicular chain

Now let us suppose there is a stapes fixation This may produce a loss of 60 db or more Disarticulating the ossicular chain in this case will not produce more loss because the stapes is immobile and useless Although there is sound going in only one window the fluid can not respond to the vibration because it is blocked off at the other end by the fixed footplate of the stapes

In this case the first thing to try is, of course, breaking these adhesions to re-establish a normally moving chain If successful this is ideal, because the normal situation is restored, but, if this cannot be done, there are several pro-

CLOSING DISCUSSION

Merle Lawrence, M D , Ann Arbor, Mich
Victor Goodhill, M D , Los Angeles, Calif
George E Shambaugh, M D , Chicago, Ill
C M Kos, M D , Iowa City, Ia
E P Fowler, M D , New York, N Y
Philip E Meltzer, M D , Boston, Mass
Samuel Rosen, M D , New York, N Y
Howard P House, M D , Los Angeles, Calif

Moderator Howard P House, M D Two years ago in Montreal, this panel analyzed its combined knowledge and efforts regarding stapes mobilization Today this same panel will bring to you newer thoughts and concepts in our thinking regarding stapes surgery during the past two years

In the interests of time conservation your Moderator today will ask each member one or two critical questions This will allow more time for audience participation and discussion at the conclusion of the panel presentation

First, I would like to call on the new member of our panel—Dr Merle Lawrence, will you discuss the function of the middle ear as related to stapes mobilization surgery?

Merle Lawrence, Ph D , (Ann Arbor, Mich) In order to speed the discussion along I shall use the blackboard to draw a schematic diagram of the ear, so that we can see what happens when we change parts of it We have the malleus (drawing on board), incus, stapes and inner ear, which I draw diagrammatically to show the endolymphatic system surrounded by the perilymphatic This gives us a picture of the normal ossicular chain, the drum membrane, malleus, incus, stapes and the scala media

The first essential for the production of hearing is the presence of the sensory cells, they must be present in the scala media and available for vibration The second item of importance is the relay of vibratory energy to these cells The primary purpose of the ossicular chain is to provide a match between the air and inner-ear liquids so the vibration can get into the fluids surrounding the sensory cells and again produces a drop in the response Removal of this plug brings the response back to the both-windows-open condition Obviously, in the presence of a normal inner ear the worst condition, aside from having both windows blocked, is to have one window closed and the other opened In the presence of a fixed stapes the situation can be improved by mobilization or temporarily by the drastic procedure of pulling the stapes out of the oval window

In the above experimental procedures the incus had been removed, so the drum membrane and its attached malleus were useless, having no direct connection with the mobile stapes or open window By removing this barrier to the sound, the response improves even further

The second slide shows the audiometric results for several frequencies The one curve shows the loss produced by the fixed stapes and the second shows the loss, a considerable improvement over the original condition, of mobilizing the stapes (and removing it) plus elimination of the drum membrane, malleus and incus It shows that through these procedures a marked improvement in hearing can be produced temporarily in the laboratory It does not indicate what the permanent results would be or what surgical complications would be encountered in the human

Despite the demonstrated improvement the average theoretical results would still show a hearing loss of about 45 db This is not enough of an improvement To be practical 15 more db must somehow be restored There is another mechanical property which can be considered in attaining this additional 15 db

We have mentioned that this 15 db loss is produced by sound hitting both windows in phase and with equal intensity This can be prevented by creating a situation that leaves one window open to the sound and protects the other without blocking it, that is, leaving it free to act as a relief point for the in-and-out motions of the other window

There are two ways by which such a situation can be accomplished one is by means of a skin flap over the open oval window or over a fenestra in the horizontal canal (as in the cedures that can be carried out which, if successful, can return hearing to the 45 db level

One of these procedures is to pull or break the stapes out of the oval window I would like to present two slides which show the results of such an operation on an experimental animal It is remarkable that the stapes can be pulled out without greatly changing the cochlear response from that produced with a mobile stapes with no ossicular chain

I would like to emphasize one thing at this point I am not advocating surgical procedures, I am talking about the mechanical properties of the ear under various conditions of surgical rearrangement in experimental conditions

In the first slide is shown a running-time record of the electrical response from a cat's cochlea when presented with a continuous 2000 c p s tone Such recordings are made possible by an electronic system which I shall not describe At the beginning of the record the stapes is fixed This is accomplished in the anesthetized cat by inserting a needle deeply into the cartilagenous portion of the Eustachian tube, a procedure which directs the remainder of the needle in a posterior direction directly past the stapes, wedging it against the promontory

The incus is removed, a procedure which, as long as the stapes is fixed, produces no change in the response Mobilization of the stapes by removing the needle, under these conditions, gives an improvement of about 12 to 13 db

As seen in the slide the next step is to pull out the stapes completely and, momentarily there is no change in response from that of a mobile stapes Such operations were separately reported as a surgical procedure on humans in 1892 by Blake and Jack, however, they soon abandoned it

Our next step, referring again to the slide, was to investigate the nature of sound transmission under the above conditions First, the now-open oval window was plugged solidly by pushing wax down into the niche There is an obvious drop in the response The response returns upon removal of the plug Plugging the round window in the same way we see an almost exact duplication and progression of techniques tried and abandoned years ago At first, in the final decade of the last century, there was mobilization which was followed by stapes extirpation and holes drilled in various regions Holes were drilled through the stapes, through the promontory, into the posterior canal and finally the horizontal canal I predict that in about 1980 somebody is going to rediscover fenestration of the horizontal canal

MODERATOR HOUSE Dr Lindsay, would you please discuss the pathology of extensive otosclerosis that might require footplate techniques for successful stapes mobilization?

JOHN R LINDSAY M D (Chicago, Ill) The histopathology is the one factor of stapes ankylosis which does not change, but as years go on we are more aware of the many variations which exist I thought it would be most informative to show a few of the really extensive cases of otosclerosis which would need some procedure directed at the footplate in order to be mobilized successfully

I am indebted to Dr Hilding of Duluth and to Dr Keeler of Oakland for the four specimens that will be shown

The first two slides are from Dr Hilding's case The first slide shows four sections through the same stapes to show how the condition varies Near the upper border the footplate is free at one side but extensively involved in otosclerosis and fixed at the other edge The section further down shows the fixation and greater extension of the otosclerosis Further down it extends well over the footplate, but still the posterior border is free in its upper part Lower down there is still a part of the footplate free where it is connected with the posterior crus The anterior crus is hopelessly involved in the otosclerotic mass This, as you see, suggests that the procedure first suggested by Fowler might be adaptable, that is, an anterior crurotomy and mobilization of the remainder of the footplate by creation of a fracture, leaving a mobile part of the footplate connected through the posterior crus to the remainder of the chain

The second slide shows a more difficult problem The situation is essentially the same in that part of the footplate is

Lempert operation) which then is so attached that an air space is left around the round window but at the same time acting as a barrier between the sound and this window Any opening in this barrier will, of course, not bring about the desired improvement

Another procedure is theoretically possible in the case of a firmly anchored stapes This consists of opening up the middle ear cavity by removing the drum membrane, malleus, and incus, which are useless in the face of an immobile stapes, and making a *minute* hole into the vestibule of the inner ear This hole must be small, because it has to offer acoustic resistance to the entering sound Such resistance cuts down the intensity of sound entering on the vestibular side and thus reduces the cancelling effect Any larger hole, such as was produced in the experiment shown on the slide by pulling out the stapes, offers no resistance at all to the incoming vibrations The tiny hole reduces the inner-ear cancelling effect and acts as a mechanical relief point for the unimpeded sound entering through the round window, so it is possible to obtain, by this method, an improvement up to the average theoretical level of 25-30 db as in the fenestration operation, and depending upon the natural acuity of the operated ear the results may be even better in some cases

I would stress that aside from the mechanical considerations mentioned here there are many physiological and medical problems involved Making a small hole in this manner may be fraught with dangers because it involves sticking into the vestibule a sharp instrument which could puncture the utricle and so injure permanently the endolymphatic system, also, the hearing results following such a pin-point perforation would more than likely fail to be permanent

If the initial attempts to restore a normally-operating ossicular chain through mobilization of the ossicular chain fail, it appears, when all factors are considered, that one should, for the patient's sake, resort to the now-proven fenestration operation despite the various other mechanical possibilities

Something should be learned from past experience, but quencies and the demonstration of a negative Rinne with the 500 and 1000 cycle tuning forks

2 A bone conduction threshold not lower than 40 db in the speech frequencies

3 A speech discrimination score with PB words not lower than 75 per cent.

4 Unilateral cases, if carefully confirmed by Weber lateralization, by quantitative masking and by Barany noise machine masking, providing that there is an expectation to reach the 30 db level, thus giving that patient the possibility of restoration of binaural hearing

5 It is pretty much our unanimous feeling that the poor ear should be done first

6 In general we do not urge or recommend simultaneous bilateral surgery

7 The choice of time for the second ear should be several months, about four months later at least

These represent our feelings about minimal requirements for primary surgery

Now as to revisions in general, chances for improvement are best with the first operation and become considerably less with successive reoperations

The surgical observations of the surgeon at the time of the first operation are often crucial in a decision regarding revision (From here on there appeared quite a diversity of opinion about revisions, and I am going to give them to you as we discussed them)

a Some on the panel felt that disruption of the ossicular continuity at the initial operation would be a contraindication to further surgery

b Others felt that such disruption would not contraindicate revision attempts by the use of newer techniques

c Some advise revision if there was no improvement at the first operation, if the surgeon feels that a newer tech-free, and one border is free from fixation but the anterior crus is hopelessly involved in the otosclerosis and the posterior crus is also slightly involved At one point it is touching on the otosclerotic mass and is slightly fixed Here the problem would be to get this free part of the footplate mobilized and also to get the posterior crus free without causing a fracture where it is involved by the otosclerosis It is questionable whether this could be done successfully

The third slide, from Dr Keeler's case shows a different situation This footplate is completely fixed all the way around the circumference The otosclerotic mass involves the footplate so that to mobilize this footplate it would be necessary to go through fairly active areas of otosclerosis This would require some method of mobilizing the footplate, whether by chisels or by whatever method the operator might prefer

The next slide from the opposite ear of Dr Keeler's case is somewhat similar This is also completely fixed all around the circumference, and the otosclerosis extends into the footplate The crura are not too bad, although one crus is extensively involved by otosclerosis This would certainly require some method of attack on the footplate in order to have any chance of success The method of attack might vary with the particular operator

MODERATOR HOUSE Dr Victor Goodhill, will you discuss the selection of cases for mobilization? Have our thoughts regarding selection changed any in the last few years? Please discuss this problem from two standpoints First, the indications and selection for the initial operation, second, the indication for revision of the initial operation

VICTOR GOODHILL, M D, (Los Angeles, Calif) These recommendations represent the composite views of the panel There are occasional exceptions to all of these statements, depending upon the judgment and experience of the individual surgeon

Minimal requirements for selection of candidates

1 An air bone gap of at least 25 db in the speech frethe event that mobilization attempts transcrurally are not successful and before fracture of the crura has occurred The other half of the panel proceeds directly to the footplate using picks, chisels or other instruments applied to the margins to loosen it and obtain mobility All members of the panel agree that in working on the footplate any perforation that opens into the vestibule definitely increases the danger to the labyrinth Deliberate anterior crurotomy, as described by Fowler, is utilized in occasional cases by members of the panel, but in the majority of cases an attempt is made to mobilize the entire footplate

In concluding on the technique of this operation I would like to make a little statement, which was suggested to me by Jim McLaurin, that there are two operations for otosclerosis

MODERATOR HOUSE May I interject just a moment before you get to this second part, by asking you your second question?

DR. SHAMBAUGH Yes, indeed

MODERATOR HOUSE What are the thoughts of the panel on fenestration of the footplate as described by Dr Rosen?

DR SHAMBAUGH At this time the majority of the panel members believe that a deliberate fenestra in the footplate without communicated mobility from the tympanic membrane to the mobilized footplate, or fragment of footplate, in all probability will not produce a lasting satisfactory level of hearing improvement

Now may I make that last statement, that there are two operations available for otosclerosis? One is the fenestration operation and the other is the "frustration" operation, frustrating because of the unpredictability of its results

MODERATOR HOUSE Thank you, Dr Shambaugh Now I will call on Dr Kos (There is another place you might use the word "frustration" That has to do with attempting to arrive at statistical evaluation of results in mobilization surgery) nique in his hands offers hope for mobilization, which did not exist at the first operation

d Some advise revision in any case if an initial improvement regresses at any time Others feel that such revision should be done only if the initial gain persisted at least nine months Some felt that revision should be done only once, others, many times In conclusion there was no true unanimity of opinion on all of these aspects of revision

MODERATOR HOUSE Thank you, Dr Goodhill I believe we conclude from this that we all agree on the indications for the initial procedure, but again you can see apparently there is no unanimity of thought pertaining to true indication for revision or on how many times the revision should be carried out

Dr Shambaugh is going to answer two questions that I will pose to him First, what major technique changes have occurred during the past two years in stapes mobilization surgery?

GEORGE E SHAMBAUGH, M D , (Chicago, Ill) Three major developments in technique have occurred since we first assembled this panel One is the utilization of audiometric testing during the operation in the operating room This was employed by several members of the panel two years ago and is now employed by all members

The second is the utilization routinely of the operating microscope to give a magnification of 10 to 16 times for visualization of the footplate Two years ago the majority of the panel relied upon two to two and one-half times magnification, and today all members of the panel agree that the operating microscope is essential for this surgery regardless of technique

The third development, which is largely dependent upon the increased magnification of the operating microscope, is the direct attack upon the footplate At the present time approximately half of this panel start with the transcrural attempt at mobilization, either on the incus, on the neck or on the head of the stapes and then proceed to the footplate, in of 30 db or better in the three essential speech frequencies the spread between us is reduced somewhat—the range being 25 per cent to 65 per cent The average of the group in this category is 42 per cent Two years ago this figure was 35 per cent Four of the participants achieved 42 per cent or better All of the rest, but one, stand very close by Two of the panelists hit this target with a closure of the air-bone gap in every one of their cases The others ranged from 13 per cent to 70 per cent The highest figure in this category two years ago was 59 per cent

It is notable that those who have performed the most operations have in general presented the more modest statistics It may be that these panelists are stuck with less desirable statistics because they led the way through the maze of uncertainties, and now having passed on their experiences have saved the others from falling into the inevitable traps of exploration I know that some of us have been experimenting in many ways with surgical techniques, and this is not always without its indebtedness to failure

Regression of hearing following a successful surgical result is always an unpredictable barrier to permanent improvement There are at least 12 recorded concepts of regression from this group There may be more It is difficult to reconcile the wide spread among us of the incidence of regressions These range from 4 per cent to 32 per cent The average is 15 per cent, however, when one considers that some of these participants are following patients whose operations took place three to five years ago and others are following those whose operations are of less duration, one possible explanation may be derived Time takes its toll of regressions even though it be in decreasing numbers

Operations resulting in worse hearing range from 0 per cent to 8 per cent in this group, depending on at least seven definitions of what constitutes "hearing made worse" The average is slightly over 3 per cent (about the same as it was two years ago) This percentage in 7,420 operations is probably acceptable if no other complications are involved, and according to the statistics of this group it is not so severe as it was once anticipated

I will ask Dr Kos to describe to you some of these complexities of analysis, and then he will present to you our results during the past two years

Dr Kos, do these results look as though we are gaining or losing in our attempt to restore hearing through mobilization surgery?

C M KOS, M D (Iowa City, Iowa) I take this opportunity to thank each of the members of this symposium for cooperating so generously in providing me with these data Since each has his own method of keeping records it was not easy for him to extract the precise information requested, but all of them made a valiant effort to comply Some irritations were aroused One began every reply to my inquiries with "Damn all questionnaires" Another when he reached the limit of his patience suggested sarcastically that if necessary he would write my paper for me I wanted to accept his invitation Others stuck to the point in spite of having some reason to rebel and delivered without protest

I must give to Dr Jim Shapley, our Director of Audiology, and to Mrs Iles, his able assistant, the entire credit for handling the information received Had I followed their original recommendations for the questionnaire, the entire job would have been easier, but my efforts to simplify a complicated task only compounded the difficulties, so Dr Shapley and Mrs Iles did the best they could to straighten things out We have lots of figures, but to give them in detail would require more explanatory notes than there is time and space available, therefore a contraction will be presented

The ten otologists on this panel, whose experiences range from 105 to more than 2,000 stapes operations, have produced an equally varied spread of results Together this group has performed 7,420 surgical procedures to mobilize the stapes as of January 1, 1958 Two years ago the panel reported on 1,091 operations Our total successes, of at least two months' duration, range from 25 per cent to 74 per cent, depending on each individual's criterion for success Our average success according to these various standards is 49 per cent When success is precisely defined as an average pure tone threshold worse" we have agreed we mean more than 20 db worse loss than the patients had before the operation Throughout the panel there were only three dead labyrinths, and one of those occurred about a month after operation, suddenly and inexplicably There is a question whether this dead labyrinth had anything whatsoever to do with the operation There was 1 per cent of persistent perforations There was a good deal of question in the minds of the panel whether this should be listed as a serious complication

There was no facial paralysis that was permanent There were three or four that developed a transient facial paralysis after the operation They recovered, and this was annoying but not serious

There was annoying persistent vertigo in three-tenths of one per cent There was a great deal of question about the chorda tympani in the letters written to me I could summarize the ideas of the panel as follows In general it was felt that stretching the chorda tympani hard was worse than cutting the chorda tympani Some of the panel felt that any injury to the chorda tympani was a serious matter, and all thought it should be avoided if possible

I have just discussed with you the complications that were suffered by those on this panel Throughout the country the story is quite different There are several cases of permanent facial paralysis There are several dead labyrinths There are a few very annoying chronic otitis medias One case developed mastoiditis, which could not be controlled and which eventually developed a base of the skull syndrome He is still alive but has a paralysis of the nerves that go through the jugular foramen, the VIth nerve and I think the Vth At any rate he had an extradural abscess at the base of the skull, and the patient is alive, I am sure, only because of hard work and chemotherapy

Finally, I would like to mention that there have been *two deaths,* one from staphylococcus labyrinthitis followed by meningitis, which was not controlled with the most heroic therapy and operation The other—this case thought to be a hospital staphylococcus that was resistant to all chemo-

Our experiences of the past two years indicate that significant progress has been made in stapes mobilization We are now aware that regressions continue to rob us of some of this progress and these are likely to become our prime target for investigation in the years to come

The experiences acquired during the hectic period of assembling these data point out the very important requirement for developing and establishing a common language to bridge the conceptual differences between us and others reporting in this field Several of my colleagues have also made this plea Fifteen different criteria for success, 12 concepts of regressions, and seven definitions of what is "hearing made worse" call for conferences designed and conducted to resolve these discrepancies

MODERATOR HOUSE Thank you, very much, Dr Kos

You have my sympathy and I am sure the sympathy of Dr Goodhill, because the two of us, in Los Angeles, got together before the Montreal meeting and attempted to go through this maze of information in an attempt to determine the results at that time, and you can see we were successful in convincing Dr Kos that he should fulfill his term of duty on this occasion

Now I will call on Dr Fowler, are any significant complications very frequently found in stapes mobilization surgery?

EDMUND P FOWLER, JR., M D (New York, N Y) I am sorry to report that this panel is no better sending statistical material to *me* than they were with Dr Kos, as a matter of fact, I think they were worse Perhaps I did not work as hard at it as Dr Kos did, but there was no way in which I could put figures together, that would give you any idea of the complications of mobilization surgery in a statistical fashion I believe it is most important to emphasize that the panel had about 3 per cent of cases that were made worse, as just reported by Dr Kos

You also notice that he mentioned that this ran between 0 and 8 per cent He did not point out that of the 3 per cent only a half of one per cent were severely worse By "severely so confined, in which instrumentation is so extremely limited, in which the structures must remain *in situ,* in which the surgical efforts involve a diseased area, and in which nothing is removed, so that the diseased focus remains? When bone, whether otosclerotic or not, is broken or cut through, I would assume that Nature's reparative process would sooner or later take place, and it does in many cases On the other hand, the fact remains that repair does not *always* occur, and thereby seems to refute my negative assumptions Since my topic is concerned with the prospects of stapes surgery, I must at this point declare that just as the problems of fenestration surgery were solved, these stapes problems will also be solved

A notable observation has been that many patients have reached a level of hearing to a degree that is attained less often by fenestration The joy of both doctor and patient following a brilliant result with stapes mobilization is not infrequently tempered by the disillusionment of ultimate failure, or if not in failure, in at least a recession of the hearing from the high degree of initial improvement The recession may occur not only in several weeks but as late as 20 months afterward

To my recollection, never in the history of otology has there been the development of so many techniques as in stapes mobilization The early enthusiasm for this operation stimulated the dormant inventiveness of many otologists throughout the world, and the most intricately designed instruments have appeared and disappeared For the present I do not favor mobilizing the stapes by mechanical means I believe, as Rosen does, that the mobilization is best accomplished by the sensitiveness of touch and the control of pressure in the surgeon's fingertips, and for this reason, in my opinion, no mechanical instrument, at present, can be substituted

The prospects of stapes mobilization are threatened when any otologist declares that a *promise* may be made to the patient that the hearing *will not* be worsened, and that if the attempt to mobilize the stapes should fail, the otologist *can always* resort to the fenestration procedure This statement would be true more often if the otologist knew *when* to stop therapy—is even more disturbing because of pneumococcus meningitis This patient seemed perfectly all right for 10-15 days, except for a little suppuration, which is not too uncommon in the early cases, (even for this panel) but suddenly a few days after his last visit to his otologist he developed a coma with a pneumococcus meningitis which was not controlled by chemotherapy and he died

MODERATOR HOUSE Now I should like to call on Dr Philip Meltzer, who will give us some of his views pertaining to the past, the present and the future of stapes mobilization surgery

PHILIP E MELTZER, M D (Boston, Mass) It is my intention to offer a word of warning that the procedure of stapes mobilization should be undertaken with a complete awareness of its pitfalls

This operation has fired the imagination of otologists throughout the world, and aroused in the mind of the layman a reaction brimming with hope for the alleviation of deafness So many procedures for stapes mobilization have been devised that the time has come for a discussion of their rationale It has never been denied that the restoration of the ossicular chain as a mobile unit for sound transmission is not valid, therefore, this operation stands on firm ground Whether or not a stapes once liberated will continue to remain so, and which of the many procedures will accomplish this most often and permanently, are questions to be discussed at symposia of this kind

I have observed the technique of some of the most practiced surgeons of this country, and my critical evaluation of this operation and my queries for the future are based on what I have witnessed, and my own experience

In fenestration surgery we are confronted with several problems Serous labyrinthitis and regeneration of bone in the fenestra are chief causes of failure Surgical access to the critical area for making the fenestra was not too difficult, and, as you are well aware, the continued advance in technique practically insures the success of this operation in well selected cases, but what can we look forward to, anatomically and surgically speaking, in the region of the stapes—a region to how it feels to have started all this stapes surgery On April 2, 1952, while I was testing a patient to see whether his stapes was rigid enough to have the Lempert operation I mobilized the rigid footplate of the stapes by pressure on the neck and the hearing improved immediately That patient still has normal hearing I think that had I or anyone else like Rip Van Winkle, gone to sleep on April 3, 1952, and awakened today to hear this panel and see the beautiful demonstration of middle ear structures by Dr Hough, he would feel that a very pleasant dream had indeed come true

It is very impressive to hear Dr Merle Lawrence give us some understanding of the mechanism by which hearing is restored by my fenestra ovalis procedure

I would like to show one slide to demonstrate whether it is possible to have lasting improvement following fenestration of the oval window Of 141 successful cases, eight or 5 7 per cent, have regressed partially 5 per cent have regressed completely and the number that have maintained the hearing improvement is 89 3 per cent of these 141 cases We have data on 72 of these successful cases for periods of three months to a year, on 57 cases for periods of one to two years and in 12 cases the hearing has been maintained for periods of two to three years

I should like to say to this entire Society that I was wrong when I said that this was a simple operation I would like to erase that from the minds of all of you It is not simple, and as time goes on it becomes more exacting

Moderator House We will now call upon our official discussors to give us three or four minutes of discussion of their experience, whether they agree or disagree with those on the panel, or give any newer thoughts they might have to offer at this time in their opinions of mobilization surgery during the past two years First, I will call on Dr Bellucci of New York

Richard J Bellucci M D (New York N Y) I am sure the official discussers are privileged on this occasion as they are not limited to discuss only Dr House s one question

I have two or three points I would like to make first in our experience in order to obtain a consistently satisfactory improvement in in his desire to free the stapes, and ceased to pursue traumatizing techniques that may preclude the fenestration operation

I now want to discuss the delicate and controversial issue of the otologist's qualifications for the performance of this type of surgery The stapes itself is so variable and fragile in structure, so loosely united with the incus, and so deeply placed in the fossa in such close relationship with the facial nerve, that this area is particularly vulnerable to accidental injuries and fracture, in the hands of even the most competent surgeons Just as the casualties of bad fenestration surgery have been observed over the years, we are now observing the casualties of bad stapes surgery The surgeon who is trained, but inexperienced, should not even consider attempting this procedure without first observing and learning in the most painstaking manner He must also be trained in clinical audiology as well as in all phases of temporal bone surgery, so he will be equipped to render a complete service to his patient

It is easy for me to stand before you and make these stipulations, but where is a man to get this kind of training? That is a problem that those persons in charge of residency training programs must solve by providing the training that will insure competence Perhaps another solution will be that the more experienced otologists will act as preceptors in their private practices, or that teaching institutions will provide courses for qualified men

Each one of us should examine his conscience to determine whether we are honestly equipped to perform the delicate maneuvers mandatory for the procedure of stapes mobilization Then and then only can we give to the patient the type of care that is so rightfully expected of us

MODERATOR HOUSE Now I will call on Dr Sam Rosen to tell us of any comments that he would like to make regarding this work Further, I would like to ask Dr Rosen this one question, how does it feel to have stimulated all of this interest in otosclerotic surgery?

SAMUEL ROSEN, M D, (New York, N Y) (Closing) I don't know quite how to answer Howard House's question as for the mobilization operation Here is one where the facial nerve and the promontory have reduced the oval window niche to a slit and the footplate is of course not visible This case is anatomically unfavorable for mobilization operation

(Slide) Where there is a large otosclerotic mass involving the whole footplate mobilization is a difficult procedure and I believe fenestration is the procedure of choice

(Slide) Here where both crura are affixed by the otosclerotic lesion even though the footplate is blue and does not show evidence of infiltration the final result is usually not satisfactory as the continuity of the ossicular chain cannot be preserved

MODERATOR HOUSE I would now like to call upon Dr Frank Sooy of San Francisco

FRANCIS A. SOOY M D (San Francisco Calif) I would like to show you very briefly four types of cases that can we feel be confused in the pre-operative diagnosis of clinical otosclerosis

Many otologists have been increasingly concerned with the number of patients seen in consultation who present ordinary office puretone audiograms which are typical of otosclerosis but who on further study or surgical exploration are found to have some other clinical condition.

The excellent paper presented by Dr Howard House at the American Otological Society calling our attention to 26 cases of congenital anomalies of the stapes footplate simulating otosclerosis is one such condition wherein confusion might arise particularly in children His finding on this syndrome in 1 per cent of his stapes mobilization cases is particularly significant as is the fact that in most instances this can be established clinically before surgery

We feel that the time has now come to evaluate critically our conductive hearing losses in order to catagorize these patients into favorable cases and unfavorable cases and we are now putting our first 500 cases on punch cards in which over 500 items are indexed in order to evaluate various pre-operative tests in the hope that a more accurate prognosis can be made by means of more complete preoperative testing

Four patients illustrating diagnostic problems are presented

I Congenital Stapes Anomalies

This seven year-old boy (see Fig 1) was recognized as an anomaly preoperatively by the presence of hand deformities and was successfully treated in the premobilization period by fenestration

II Unilateral Complete Hearing Loss with Inadequate Masking

Fig 2 shows the usual unmasked office audiogram in this condition while Fig 3 demonstrates the effect of masking at the usual maximum of 50 db with the ordinary audiometer Fig 4 reveals the true audiogram when masking is carried out at levels of 90 db under research conditions using white noise or sawtooth masking Since many audiometers provide only 50 to 60 db of masking this is a real problem

III Use of Psychogalvanic Skin Reflex Audiometry (PGSR)

Fig. 5 shows the audiogram of a five-year-old girl who was referred for stapes surgery on the basis of PGSR testing only Subsequent study by conventional methods using an audiologist trained in children s testing reveals a pure perceptive loss (see Fig 6) hearing the continuity of the ossicular chain must be maintained, therefore, techniques which depend upon the strength of the crura for mobilization have been discarded, and all forces are applied directly to the footplate at the point of maximal fixation With the microscope and with direct visualization of the point of the needle it is possible to obtain visual as well as tactile control

We have done considerable experimental work on animals, have fractured the footplate, have removed the stapes from the oval window and a variety of these operations We have found that considerable tissue reaction occurs following trauma to the oval window, and we have experimentally induced stapes fixation by these traumatic procedures We believe that mobilization of the stapes operation should be done with the least trauma to bone and mucosa This operation should be a gentle procedure done carefully and slowly, exploring the weaknesses in fixation which will permit mobilization by the simplest means A very careful pre-mobilization evaluation of the pathology, therefore, is required before mobilization is attempted By this pre-mobilization examination we are able to understand the pathology and to modify the technique of mobilization accordingly In using the simplest means of mobilizing, trauma to the stapes and footplate is reduced

If we can leave the joint and the stapes mobile and as normal as possible we believe we have achieved our goal I believe that excessive trauma will certainly induce refixation

I would like to show the classification we use as a guide for stapes mobilization

(Slide) We have devised a classification based on the anatomical and pathological findings, the degree and position of the otosclerosis at the footplate This is Class I the characteristics of this Class I can be summarized as follows Show no narrowing of the stapedial vestibular joint, the footplate is blue, palpation of the posterior end reveals motion, and palpation of the anterior end reveals that there is some degree of fixation, 36 per cent of the cases studied were found to have the characteristics of Class I It is obvious here that any technique will mobilize this type of fixation, however, we placed the needle point right at the junction of the crus and the footplate Slight pressure usually causes mobilization

(Slide) Class II the characteristics of Class II are narrowing of the stapedial vestibular joint but not involving the anterior crus or then it may be the posterior crus The footplate is blue, due to the flexibility of the stapes slight motion can be seen on palpation at one end of the footplate In this slide at the anterior end there is definite fixation Sometimes the footplate is involved as shown In this group we find the most difficulty as it requires the application of the mobilizing forces directly to the point of the otosclerotic fixation having to go through the lesion and causing some degree of trauma We therefore have the highest *rate of refixation in this type of case There were 41 per cent of these* cases in our study, which means that the largest group belongs to this Class II

(Slide) Class III is advanced otosclerosis involving the anterior crus, the footplate and the vestibular wall Only 14 per cent of the cases were found to be in this group Mobilization in this group of cases is done by means of the anterior crurotomy of Fowler where the lesion is circumvented Part of the footplate and one crus operate together for the transmission of sound to the oval window The anterior crus is divided above the otosclerotic lesion at this point

(Slide) In Group IV we have the group of cases which are unfavorable

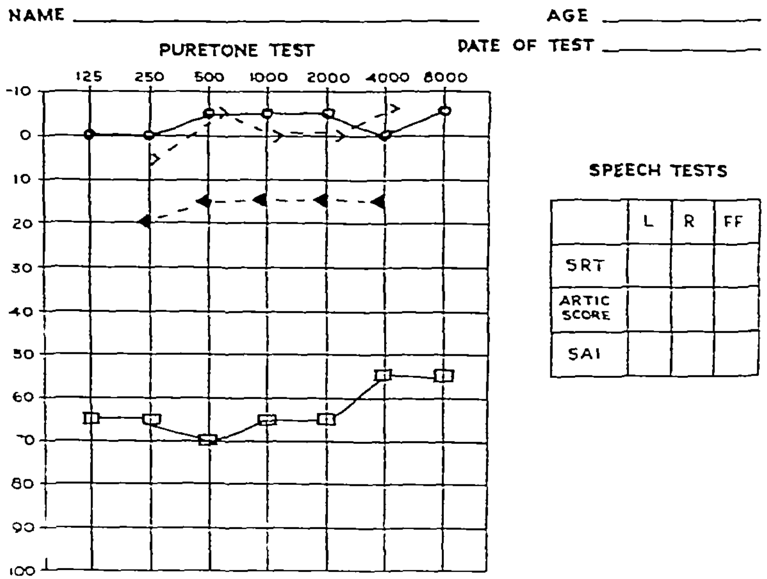
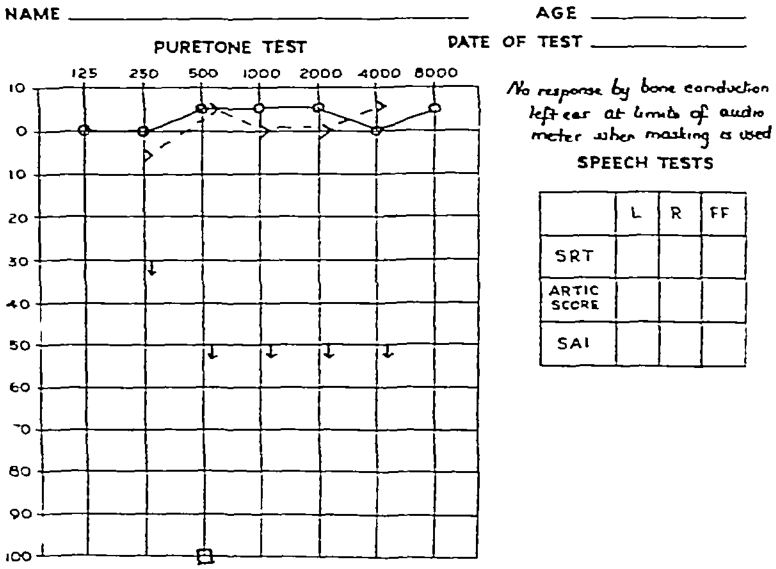
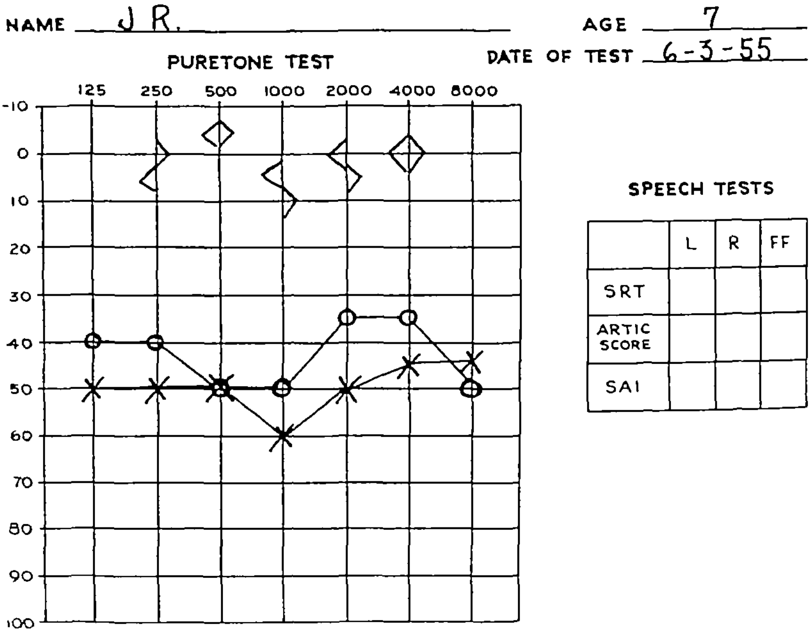


Fig 3



No response by bone conduction
left ear at limits of audio
meter when masking is used

Fig 4



NAME J R.

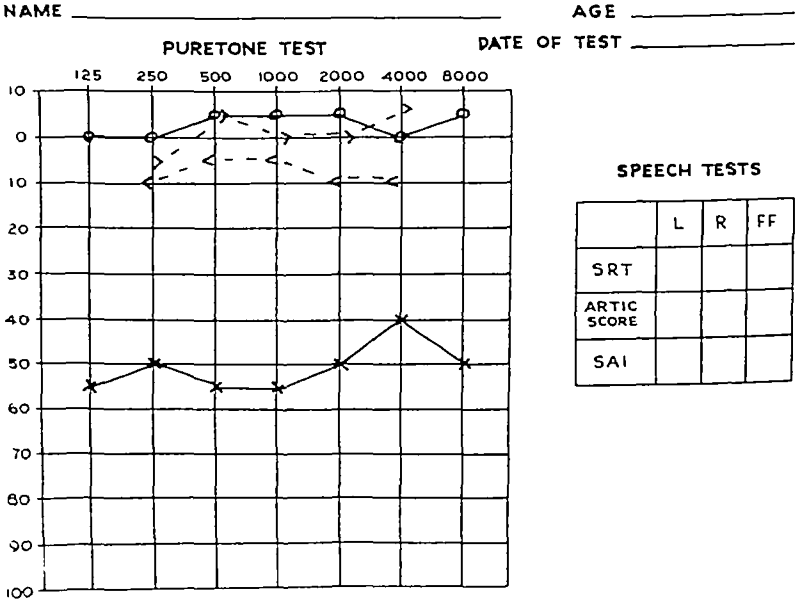
AGE 7

DATE OF TEST 6-3-55

SPEECH TESTS

	L	R	FF
SRT			
ARTIC SCORE			
SAI			

Fig 1



NAME

AGE

DATE OF TEST

SPEECH TESTS

	L	R	FF
SRT			
ARTIC SCORE			
SAI			

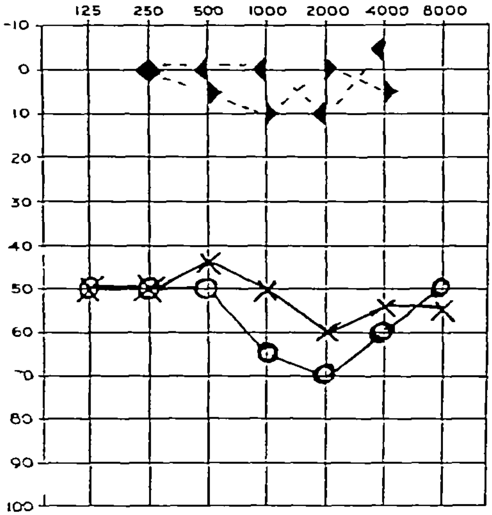
Fig 2

NAME A D

AGE 26

DATE OF TEST 5-13-57

PURETONE TEST



SPEECH TESTS

	L	R	FF
SRT	51	56	
ARTIC SCORE	98%	96%	
SAI			

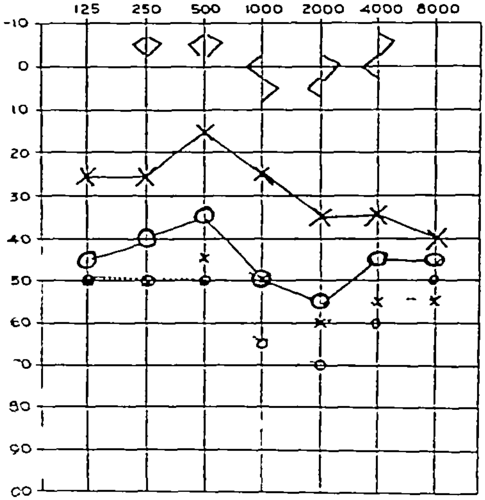
Fig 7

NAME A D

AGE 26

DATE OF TEST 6-26-57

PURETONE TEST



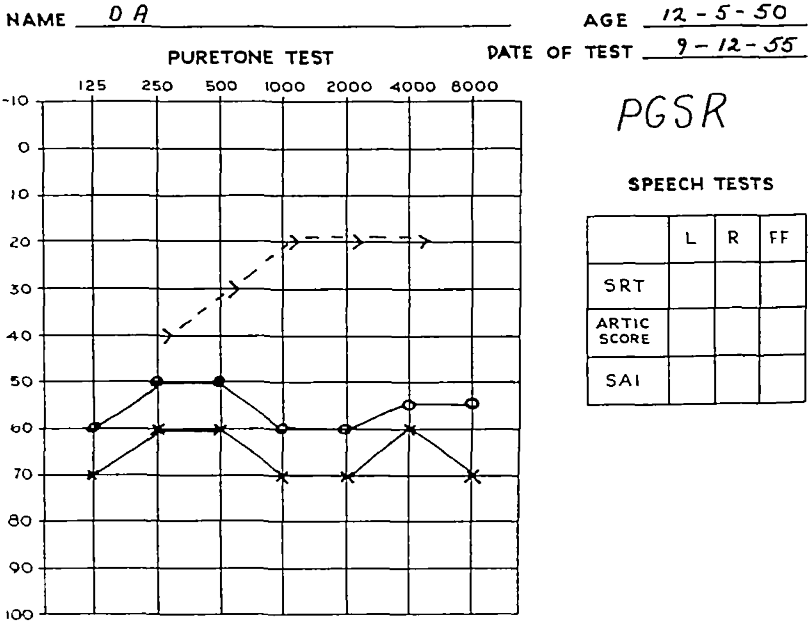
SPEECH TESTS

	L	R	FF
SRT	29	50	
ARTIC SCORE			
SAI			

puretone thresholds obtained by GSR

- - audiogram 5-13-57

Fig 8



NAME D A

AGE 12-5-50

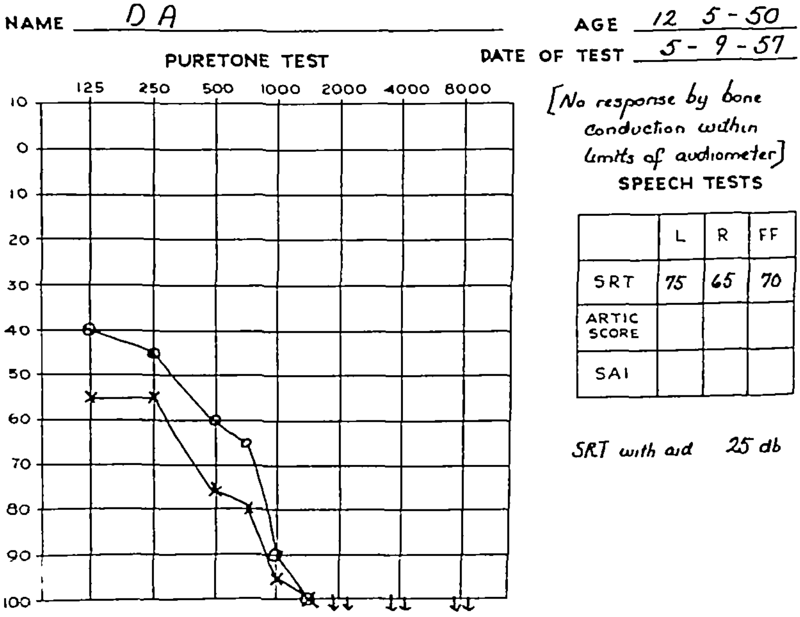
DATE OF TEST 9-12-55

PGSR

SPEECH TESTS

	L	R	FF
SRT			
ARTIC SCORE			
SAI			

Fig 5



NAME D A

AGE 12 5-50

DATE OF TEST 5-9-57

[No response by bone conduction within limits of audiometer]

SPEECH TESTS

	L	R	FF
SRT	75	65	70
ARTIC SCORE			
SAI			

SRT with aid 25 db

Fig 6

immediate postoperative level of hearing and No 3 the red line the postoperative level of hearing after two months showing an improvement in the conversational range but a sharp drop in high tones this suggested possible damage to the inner ear by the footplate manipulation When I returned home from this meeting about a month later I received a call from this man in which he stated that his hearing had completely disappeared in the operated ear Audiograms were done and confirmed that there was a complete loss of hearing (slide)

Now in this case a hole was inadvertently made in the center of the footplate What then might happen if one uses the technique as demonstrated by Dr Shea in his motion picture in which it appears that a hole is intentionally made in the center of the footplate? An occasional dead" ear is bound to result furthermore alterations in the membranous labyrinth, as illustrated in the following cases, may occur

In two patients additional complications of direct stapes footplate manipulation were revealed in subsequent labyrinthine fenestration operations In one case (slide) when the cupola was removed the membranous canal was shriveled into a brownish flat thread hugging the upper margin of the bony canal in the other (slide), a thin brown membrane suspended from the margins of the fenestra like a hammock dipping into the cavern of the bony canal was present The status of the membranous canal below this was not determined as this thin coagulum was not disturbed Fortunately both of these patients had a good hearing result fortuitous no doubt when one considers what was found in each instance As Dr Meltzer has stated the patient usually is told that if his stapes operation fails he still has the opportunity of gaining hearing by a subsequent fenestration procedure In the light of the experiences of these two cases one must be conservative in footplate manipulation to permit the maximum chance of success for a possible fenestration operation This should be a cautious circumferential manipulation of the footplate instead of a hole-punching type of procedure

Two years ago I stated that it was unwise to proceed with a labyrinthine fenestration at the same operation if it appeared that the stapes mobilization was a failure Nothing has occurred in the past two years to cause me to change this opinion

MODERATOR HOUSE I would now like to call on Dr Schuknecht

HAROLD F SCHUKNECHT MD, (Detroit Mich) I will limit my discussion to a brief description of my present technique and to an explanation of why I believe it is a rational approach It should be evident to everyone by now that it is not an easy surgical procedure and that it is not free of complications In about 400 operations I have three patients with near total deafness in the operated ear One of these resulted from simple trans incudal mobilization one from chisel mobilization and one following the use of the metallic stapes prosthesis

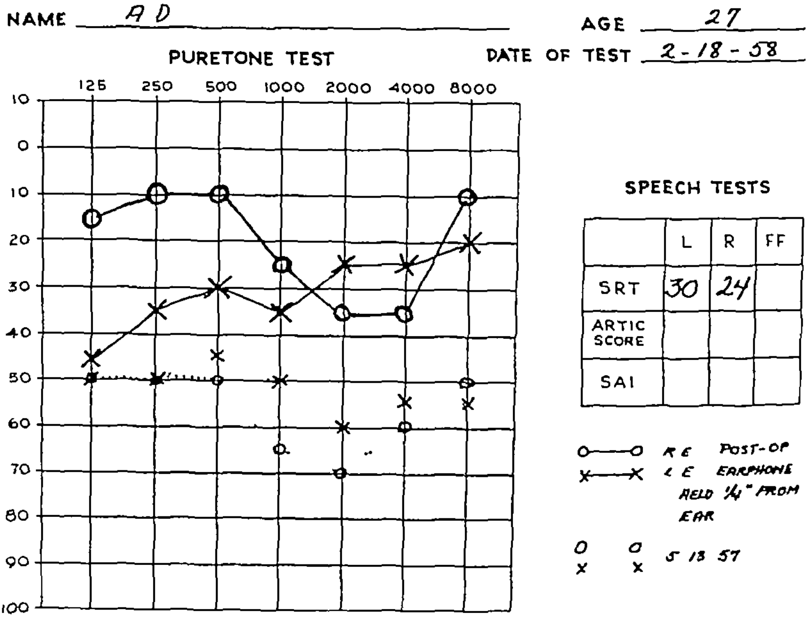
I agree that patients must be told that there is a danger that the hearing can get worse The results are good enough nonetheless to justify recommending the operation after properly informing the patient of possible complications and the chances for success

I use the direct footplate approach using the Heermann chisels In my opinion these chisels are best used by holding them in the fingers Light to heavy hammer blows are given as necessary to go through the otosclerotic focus when possible If that fails an incomplete footplate mobilization is accomplished

IV Collapse of Ear Canal Due to Headset Pressure

Fig 7 shows consistent puretone and speech tests in a 26 year old girl whose response to spoken voice was somewhat better than her audiogram PGSR testing (see Fig 8) suggested usable hearing in her left ear

Stapes mobilization revealed otosclerosis in the right ear with a gain of 32 db in this ear *after* she was tested by holding the headset a fraction of an inch *away* from her ear (see Fig 9) A similar test on her un operated ear revealed a gain from 51 to 29 db This phenomena, which has been described by Scott Reger is now called the Viehweg syndrome in our laboratory after the audiologist who discovered two such cases in recent months



NAME A D AGE 27

PURETONE TEST DATE OF TEST 2-18-58

SPEECH TESTS

	L	R	FF
SRT	30	24	
ARTIC SCORE			
SAI			

Fig 9

MODERATOR HOUSE Dr Scheer was not able to attend the meeting I will now call upon Dr Shirley Baron

SHIRLEY H BARON, M D, (San Francisco Calif) Two years ago in the discussion following the symposium, I presented two cases one demonstrating the advantages, and one representing one of the possible disadvantages of direct footplate mobilization

(Slide) This was the case I presented as the one showing the dis advantages of footplate mobilization This patient had violent vertigo immediately following surgery The vertigo persisted for four days There was some loss of balance or dizziness for about six weeks after surgery I presented this same slide showing No 1, the black line which was the pre-operative level of hearing No 2 the green line the

3 Deep focus Fixation of the stapes may be due to a deep focus which has grown onto the under surface of the footplate No visible evidence of the otosclerotic focus may be present with any magnification when viewed from our surgical approach yet the stapes may be fixed to varying degrees of slight to marked as judged by the application of pressure to the head or footplate of the stapes

4 Combined foci Any or all of the above types of foci may be combined depending upon the extent of the otosclerotic involvement The combined type is usually massive in character and usually results in firm fixation which does not yield to mobilization with our present technique

It is our belief that appropriate attempts should be made to mobilize all fixed stapes in acceptable candidates regardless of the appearance of the otosclerotic focus If mobilization techniques fail or if refixation occurs acceptable candidates are then encouraged to have fenestration surgery

MODERATOR HOUSE Now, Dr Sullivan

JOSEPH SULLIVAN M D (Toronto Can) We have been stampeded and somewhat mesmerized however I congratulate the panel on its frankness and honesty particularly the summation of the remarks of the panel by Dr Meltzer I think that the remark of Merle Lawrence will be validated in the future Coupling that remark with the excellent contribution of Dr Hough and to which Dr Sooy referred today this procedure may resolve itself into an approach of congenital malformations of the middle ear rather than the moderately severe otosclerotic

From the Epistle of St. James the 1st Chapter Verses 19 20 21 Let every man be swift to hear slow to speak and slow to write

I believe I must emphasize that latter phrase briefly I make a plea for a uniformity in terminology correct in basic English namely stapes mobilization with a mental reservation that this term may not be entirely accurate

Three surgeons Dr McAskile Dr Smith and myself have evolved a technique and this was written before the panel remarks came for stapes mobilization which in a series of about 500 cases is yielding a 30 db or better level of hearing in about 40 per cent of the cases for one to four months following operation for cases suitable for fenestration There are exceptions they are few in number Roughly half of all our mobilization cases fail to achieve a hearing improvement comparable to fenestration while about 3 5 per cent of all mobilizations end up with a further hearing loss of significant degree

We believe four factors should be emphasized in this procedure

1 The use of the operating microscope is essential for the best constant result and there the most important question has been answered which I had intended to interject to the panel can a fenestration always follow a non successful stapes mobilization?

2 Direct visualization of the footplate is necessary and I hereby insert a word of caution In spite of what has been said after nearly 30 years experience in temporal bone surgery that footplate perforation is not a fenestration it is a primary procedure It is frequently followed by failure and early closure and is not without danger Would someone on the panel venture an opinion pertaining to the question about the persisting vertigo and is labyrinthitis in such a patient a condition where revision of the patient may be attempted?

The use of pressure directly inwards towards the vestibule should be the principal attack in attempting mobilization and it is used only on

In about 3 per cent of cases, the oval window is filled with a plaque of hard otosclerotic bone, and a successful mobilization cannot be accomplished. With the direct footplate techniques the footplate is sometimes comminuted, the bluish thin portion is in pieces, and the crura make contact either with these fragments or sit in a pool of perilymph. The columella effect remains and a good result is possible.

Eighteen months ago, I performed a repeat operation on an unsuccessfully mobilized ear and replaced the previously fractured stapes with a tantalum wire prosthesis. This patient was not a candidate for fenestration surgery because of poor bone conduction thresholds. The tantalum wire was looped and tightened onto the lenticular process with the other end protruding through the remaining pieces of footplate into the vestibule. The patient acquired a good hearing improvement which has been maintained to the present time. Since then, I have used this technique on about fifty patients.

Whenever the direct footplate approach fails to result in a satisfactory columella effect because of crural injury, the tantalum or stainless steel "pin" can be used to reestablish the "columella." Often I remove the head, neck and crura of the stapes. The pins are made of .005 inch suture wire shaped into a small "question mark" of suitable size with or without a small "ring" at the bottom. The length of the "pin" is such that when the loop is tightened on the lenticular process, the distal "ring" is in contact with the fragments of footplate.

I now use the pin in over half of all mobilizations and am convinced of its efficacy.

MODERATOR HOUSE: Now I should like to call upon Dr. Fred Guilford.

FREDERICK R. GUILFORD, M.D. (Houston, Texas): We do not believe it is possible with our present knowledge to classify a stapes as to its possibility for mobilization by the appearance of the otosclerotic focus present. It has been our experience that the examination of the otosclerotic focus alone during the stapes mobilization operation, with our present methods using magnification of from 6 to 25 power, does not give us adequate information concerning the possibility of its mobilization.

The relationship of the plane of the otosclerotic focus to the plane of the footplate as well as the extent of the otosclerotic involvement are important factors which may govern the possibilities of surgical mobilization of the stapes.

The relationships of the otosclerotic focus to the level of the footplate may be given a surgical working classifcation as follows:

1. *Superficial focus.* The main body of the focus is above the level of the footplate. Impingement of the focus on the anterior crus or onto the superior surface of the footplate may be the cause for the fixation. A focus of this type may be quite large and yet the stapes can be readily mobilized. At times the whole superficial focus mobilizes with the stapes.

2. *Interstitial focus.* In this type of involvement the fixation is due to a focus which apparently grows into the substance of the footplate without marked overgrowth of bone above the level of the footplate. In this type the white otosclerotic bone can be seen extending from the periphery into the blue-gray footplate often giving the appearance of the gray white arcus senilis seen in the cornea. This type of fixation is often strong and rigid. Mobilization effected in the presence of this type of involvement may be associated with a linear fracture of the footplate parallel to the margin otosclerotic focus in the footplate.

those that are obtained from fenestration, and the percentages of success from fenestration are infinitely higher

Moderator House I would now like to call on Dr Moses Lurie of Boston

Moses H Lurie, M.D (Boston Mass) I think this is the most stimulating discussion that I have heard on mobilization of the stapes but as I listened I suddenly became aware of the fact that it was not mobilization of the stapes they were talking about. They were talking about various operations on the vestibular part of the membranous labyrinth Each man seems to have had his own idea how to approach and how to play with it Until we get a standard method upon which we can all agree we are never going to get any statistics We must know exactly what each man does and we must give each man s variation of the operation a definite place in this work There is no question in my mind that mobilization will find its place It is just like the arguments that came up with fenestration I know all the vicissitudes and variations which we went through and now are going through again

I heard some statements which upset me a little bit One was, if you are going to do bilateral mobilizations of the stapes wait four months I would wait a much longer time I would wait over a year, because you still have the possibility that you may give this patient bilateral deafness and one must always respect the sensitivity of the membranous labyrinth

I do not think the criteria of success are definite enough One talks about four months two months three months No case is a success in my mind even in the fenestration cases that does not have good hearing at the end of one year After a year—then you can start talking about success for mobilization The one thing I would like a good many of you to carry away with you today is as Dr Meltzer said that you must practice this type of operation I started to work with it and gave it up because I found that I could not accomodate my eyes to this type of work but there is no reason why the younger men cannot do it and carry on

The other thing I would stress is the demonstration that Dr Lawrence has given you about what the drum and the ossicles do in regard to transmission of sound Remember, cracks in the footplate may give you good hearing for a short time, but you are playing with a pathological process which you have not stopped and which may destroy all your effort in one or two years Then the patient will be back to where he was originally

Moderator House Thank you, Dr Lurie I should like to now call on Dr Tonndorf

Juergen Tonndorf M D (Iowa City Iowa) When Dr Rosen asked me whether I would like to discuss the principles involved in footplate fenestration I did not know what my good friend Merle Lawrence had to say on this subject Now I feel a little embarrassed All that remains for me after his lucid presentation is to amplify some of the points

In trying to bring the acoustic task of the middle ear upon a simple denominator one might say that this task is twofold first impedance matching second preservation of the phase difference between the two cochlear windows The latter for reasons of cochlear mechanics has a value of 180°, however I would like to point out in this connection that the way nature has solved these two tasks is by no means the only the footplate or crura at the very beginning and the end We test the mobility of the stapes by the lightest pressure on the incus and that sense of touch can be very well developed in animal experimentation on nerves Working on either side of the anterior crus, if possible is preferable not through the otosclerotic focus, because this region has a tendency to fracture

Finally a few words of caution concerning the facial nerve There may be a dehiscence in the facial canal as it runs along the upper margin of the oval window so that the unprotected nerve sheath bulges in the oval window To quote Cawthorne, there is plenty more to do, and whether to push it or rock it, or pull it, or perforate it, or remove it and bypass it, the stapes deserves all the critical attention we are able to devote to it

In conclusion, there are many arts among men, the knowledge of which is acquired by experience For it is experience that causes our lives to move forward by the skill we acquire while the want of experience subjects us to the effects of chance

MODERATOR HOUSE I am sure that these thoughts are likewise those of the panel Now we have had several who have indicated their desire to discuss this We have in mind also to call on a few more who are not sure at the moment that they are going to discuss it, who have not turned in their cards First of all I will call on Dr Theodore Walsh

THEODORE E WALSH, M D (St Louis, Mo) There are just one or two remarks I would like to make I agree with Dr Meltzer emphatically when he remarks about being honest with the patient and in telling the patient that he can not always have a fenestration if a mobilization fails I agree that usually one can do a fenestration when a mobilization fails but not always

I had a case which illustrated this to my great sorrow A girl who was an ideal candidate for fenestration, a nurse, who needed her hearing, consulted me some three years ago She refused fenestration at that time and recently came back demanding the stapes mobilization She asked me, 'Suppose this fails, can I have a fenestration?' and I said, 'As a rule, yes, but accidents can always happen, and we might not be able to do it I still advise a fenestration'

She insisted on the mobilization, and we did it with the very greatest of ease This was an extremely easy case, and the hearing on the table came up to the 15 decibel level, however, when I removed the drapes feeling very pleased with myself for having mobilized her stapes, she remarked that she was very dizzy

She had no nystagmus but did remain extremely dizzy, vomiting and unsteady on her feet, and three weeks later had a completely dead ear She has not forgiven me

I believe one should be very careful in all the work one does around the footplate It is very nice if one can mobilize a stapes easily, but if there is any chance of damaging the hearing by excessive efforts at mobilization I believe one should quit and do a fenestration later Incidentally I agree with Dr Sullivan when he says that the hearing results from mobilization are no better than they are from fenestration In reviewing all our cases of both fenestration and mobilization there are very few mobilizations that have a residual hearing level better than

Dr Kenneth M Day I would comment on the comparison of the hearing following fenestration and mobilization There must be a dozen patients upon whom I performed a fenestration some years ago and have recently mobilized the stapes of the other ear In half of these cases the hearing level in the fenestrated ear and in the mobilized ear is almost the same

One of the patients happened to be a young musician He has music in his fingers Discrimination scorers are the same but he said 'I like the first ear for music" There is a little distortion in his mobilized ear Most of the patients upon whom I have done a mobilization on the second ear say I may hear as well in the mobilized ear but I seem to hear more clearly in the fenestrated ear"

Is that due to traumatic labyrinthine reaction from working around the footplate? We are always worried about trauma when we make a fenestra in the horizontal canal I wonder if this is not a case of more traumatic reaction in the cochlea by working on the footplate than back in the horizontal canal

Moderator House Now we will hear from Dr Hoople

Gordon D Hoople, M D (Syracuse N Y) This has been most interesting There are many things that one could say but I want to confine my remarks to one aspect of the whole subject and that is none of us should go away from here thinking that we have the final answer on the chances of percentage of success Dr Kos has told us the reasons why There is a figure projected which shows 42 per cent as the overall results of all the panelists If I interpret the presentation correctly this is the result of all their cases to the present time It includes some of the cases that were not successful in the very beginning of mobilization surgery I am afraid that it also includes some cases which the panelists have done by footplate manipulation which in three months six months a year or more from now may not have as good hearing as they have reported at the present time

I have some evidence which is not ready for presentation now that footplate work is spoiling some of the results of men who did not formerly attack the footplate One member of the Society who has spoken this morning stated at Philadelphia at the Midwinter Meeting that he had 72 per cent successes in doing mobilization surgery but in four months 17 per cent of these had regressed to the former hearing level (These are his own figures Maybe I have missed out by one or two per cent but that is not the point) I am not belittling him at all but this is success of an operation but not success in producing better hearing as far as the patient is concerned So we will have to wait a long time before we know what the results are and we must take into consideration the present rash of footplate manipulations I use that word advisedly

Finally I would like to say one thing which I think most of us have forgotten The last word that was said in the panel two years ago in Montreal was said by the man who today would be the President of this Society had he lived He himself was not a fenestrator but he said this 'I believe that this work should be done by men who know fenestration surgery I leave you to put whatever interpretation you wish on his words but I want to remind you that he said them

Moderator House Now with the passage of time I take this opportunity to return to the panel for any closing comments they might like to make way this can be accomplished I would illustrate this point with the aid of three slides

(Slide) This first slide shows a schematic diagram of the normal middle ear Impedance matching is accomplished by application of the transformer principle the large ear drum is coupled to the small footplate via the ossicular chain In the lower drawing a different approach is used, one which is widely applied in engineering, the so called acoustic horn This horn accomplishes essentially the same that the ossicular chain does in the upper drawing I admit that within the limited space between the pinna and the window, a horn would be somewhat unsatisfactory at low frequencies that is below 500 cycles

(Slide) Now we come to the second task the preservation of phase differences In this slide I made up two theoretical cases which represent two extreme solutions of the problem The first of these solutions consists in doubling the ossicular chain Normally (the upper chain of this drawing), the eardrum and the oval window move in phase In the lower (hypothetical) chain the incus is assumed to pivot about its center so that the eardrum and the round window, to which this second chain is connected move in opposite phases This way one would obtain a drive mechanism which engineers by a very descriptive term, call a pushpull drive mechanism

The other extreme solution would consist of shielding the round window completely so as to produce an infinite impedance mismatch between the eardrum and the round window From the third drawing on this slide it is obvious that Nature does not use either one of these extreme solutions but makes somewhat of a compromise First, there is a certain amount of phase shift through the ear drum This shift is maximal namely 90°, at 1500 c p s and smaller for all other frequencies being positive at lower and negative at higher frequencies, thus the phase shift principle is operative to a certain extent The second principle is the impedance mismatch The ossicular chain represents a solid coupling system which has a high degree of energy transfer The other pathway eardrum to round window, has a lower degree of energy transfer furthermore the two windows are of different size the round window being the smaller of the two Third (not shown in this schematic drawing) the eardrum and the round window are not in an identical plane so that partial reflection might occur Of course this latter fact does not operate at low frequencies but it may become important however at frequencies above 2 000 cycles

(Slide) This last slide gives the reason why Dr Rosen s method of footplate fenestration is acoustically feasible Now both windows are coupled to the eardrum in a similar fashion, however because of the fact that the window in the footplate is so much smaller, we have a better impedance match from the ear drum to the round window and a lesser impedance match to the window in the footplate The assumption appears logical as Dr Lawrence has pointed out before that the relative sizes of these windows are very critical Without having done any measurements or experiments along this line I would venture to predict that a plot of amplitude of window motion vs size of the footplate window would first increase and after going through a maximum it would go down again At this time, I am in no position to say anything about the degree of gain one might achieve by this method and of course it is completely out of my province to say anything about the probability of postoperative changes *The only thing I would point out here is that* this method is acoustically feasible

Moderator House Dr Day, may we have your comments?

tion by one of my associates in which the crura were fractured at the same time the footplate was mobilized and you will notice the further loss of hearing by air and the increase in the air bone gap due to discontinuity of the ossicular chain despite a successful mobilization of the footplate Two years later the patient returned for revision At this revision a tantalum wire as Dr Schuknecht has described so nicely was placed between the incus and the center of the mobilized footplate and we see that the air bone gap now has been reduced to somewhat less than 50 per cent of the pre-operative level We have re-established the continuity of the ossicular chain and as Dr Lawrence has stated three times I think I would like to say for the fourth time for best results we must have a continuity between the tympanic membrane and the movable portion of the footplate

Moderator House Thank you, Dr Shambaugh Now may I call upon Dr Kos for any comments he might have in closing

C M Kos MD (Iowa City Iowa) (Closing) Well the figures speak for themselves though not very accurately for obvious reasons which have been mentioned here several times I should like to emphasize that regardless of any other concept in connection with this operation at the present time it is essentially an exploratory operation It is exploratory for two principal reasons—One is that there is no pre-operative or clinical clue on which one can hang enough confidence to predict what the outcome may be second there is no surgeon who can possibly accurately anticipate what he will find before he raises the tympanic membrane

Moderator House Now Dr Fowler, before closing I would like you also to answer the question of Dr Sullivan, namely to comment a little further on persistent vertigo following mobilization surgery as a complication

Edmund P Fowler Jr MD (New York N Y) (Closing) I think it is wise at this point to emphasize that the footplate can be mobilized in a number of ways This is my personal opinion and not held by some on the panel and that is why I left it to this time I believe that as a rule the stapes (Slide 1) is mobilized by fracture through the footplate as shown in I IV or V I also think that this is probably the best way to mobilize the stapes ankylosed by otosclerosis because if it is mobilized through the focus as in II it seems to be the ideal way to invite more closures

(Slide 2) To answer Dr Sullivan to a certain extent this is a section of the footplate of a patient in which an anterior crurotomy was done Inadvertently in testing the footplate a puncture of the footplate occurred (between the arrows) This patient died 15 months after the operation and you can see that there is tsill a spicule of bone in the labyrinth (above arrow on left) There was no infection in the labyrinth I think that if you push this spicule of bone a little further that it can be pushed into the utricle or it can rest on the utricle and produce vertigo by acting as an overgrown otolith Unfortunately we are not always as lucky as we were in this case when there is a hole in the footplate of this type If there is any infection present in the middle ear it could get into the labyrinth through such a hole

Finally I would say that the size of the hole in the footplate may make a great deal of difference as far as subsequent hearing is con

DR LAWRENCE I don't believe that there is any need for saying three times what I said, but I thank Dr Tonndorf for the amplification and would like to re-emphasize what the result will be, if one can re-establish the normal condition I leave the rest to the panel

MODERATOR HOUSE Dr Goodhill, I would like to ask you two questions one is in answer to Dr Sullivan Can cases of persistent, annoying vertigo be revised?

DR GOODHILL I have not revised any In answer to Dr Sullivan's question as to why they happen I am quite sure that they are due to permanent displacement of utricle, saccule, macula and fixation, by some kind of fixation in the vestibule

MODERATOR HOUSE Are there any other closing comments you would like to make?

DR GOODHILL I would like to make one comment in regard to Dr Hoople's statement I think he would be very happy to learn of the activities of the Committee of the Otosclerosis Study Group, which met here a day or two ago I don't believe I am going to disclose any confidences when I tell him that this committee, working up a report for the next meeting in October, has decided to eliminate three words in their recommendations for evaluation techniques for all types of conductive deafness surgery The first word is success, the second word is permanent, and the third word is total It will be our recommendation that neither of these three words be used in any reporting techniques

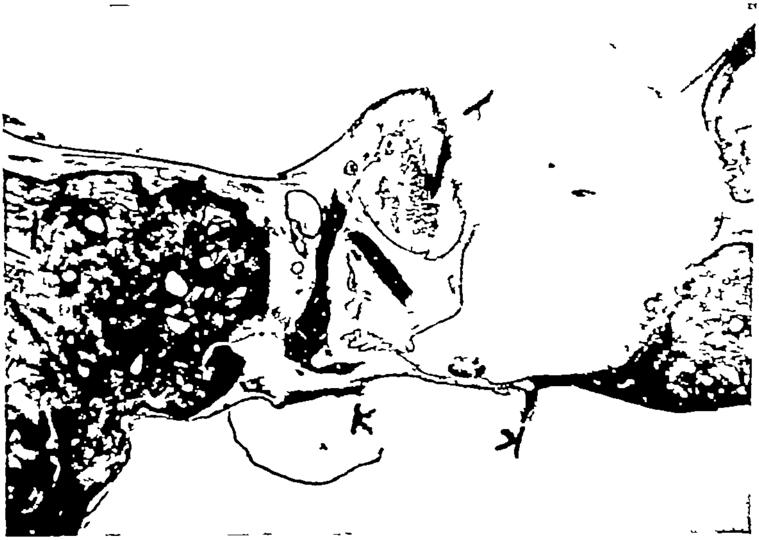
It will be our further recommendation that all evaluations be reported in two separate categories, each category being reported for Class A Class B and Class C cases The first category will be the 30 db level This is important from the psychosocial point of view This is one method The other method will be evaluation in terms of the degree of closure of the air bone gap, and the word which we probably will use will be per cent improvement, or per cent closure, of the air bone gap The word 'success" is out

MODERATOR HOUSE Thank you Dr Goodhill

I should now like to ask Dr Shambaugh for any closing remarks, but before doing so I would like to ask him in view of our techniques what are his thoughts pertaining to mobilization of a patient who has been previously unsuccessfully fenestrated on the same ear

GEO E SHAMBAUGH, JR, M D, (Chicago, Ill) (Closing) We have attempted to do this procedure in a number of cases and all of them were failures Theoretically such a procedure, if you can also perform a myringostapediopexy might be successful but in none of the cases that we have done it has there been any improvement So we feel that this procedure is not of any value

In closing I would like to show a single slide if I might This slide emphasizes some of the fundamental physiology of the ear which Dr Lawrence presented so beautifully In the upper left see the patient s air bone His is the type of case classified as Type C because of poor bone conduction but with a good air bone gap The patient had mobiliza cerned also the stiffness of the healing process Months later it can even be what the stiffness is later which produces the effects that were mentioned by Dr Lawrence and Dr Tonndorf Finally the position and overhang on the round window may also make a difference Until we understand these things we will not understand mobilization

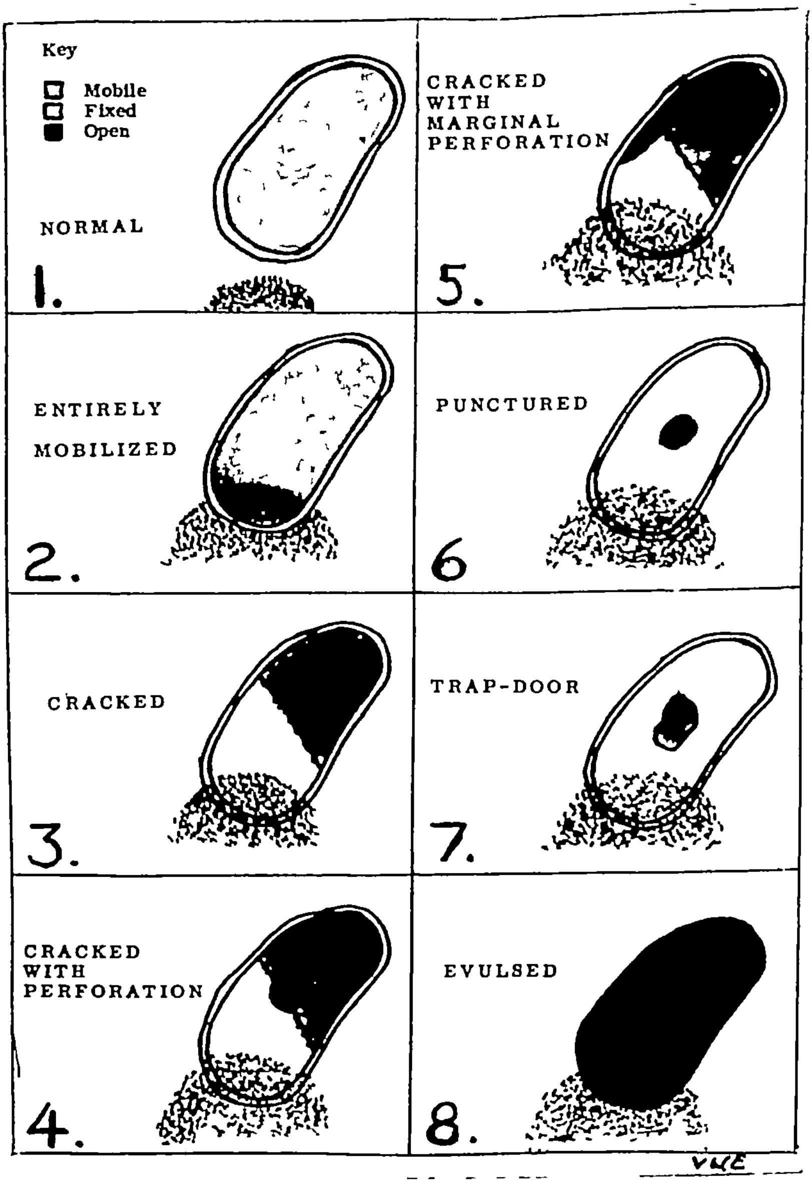


Slide 2 Histological preparation of a patient who had stapes mobilization (anterior crurotomy and footplate puncture) 15 months before his death Fractured anterior crus is shown just behind the classical otosclerosis on the left and the fibrous closure of the hole in the footplate is seen between the arrows Above the arrow on the right is a spicule of bone which has dropped downward into the vestibule and below the arrow on the left is a bit of floating endostium Note that there is no evidence of infection in the labyrinth

Moderator House It is now my pleasure to make a few closing remarks on the subject

First, Dr Lawrence has brought to this group his comments and description as to why these operations work He has also made the prediction that in the eighties we will return possibly to the fenestration operation in otosclerosis I would like to comment that the fenestration operation still offers the very best chance of restoration of hearing in suitable cases of surgical otosclerosis

Dr Lindsay pointed out by means of histopathological examination why footplate techniques are essential in some



Slide 1 Diagram of eight ways in which the perilymph might be mobilized in various types of mobilization procedures

The comments of Dr Meltzer are always highly valued for their conservatism and the prospectives of the future are well taken We grow with otology, with experience

To Dr Rosen we are grateful for his observations that have brought about this fine discussion today We are also grateful to him for having pointed out that this operation is not a simple procedure, but indeed a complex one and not without the possibility of significant and serious complications Dr Rosen stated his experience with fenestration of the footplate has been gratifying in obtaining immediate as well as lasting improvement in hearing This was not the opinion as expressed by Dr Shambaugh Only time will settle this difference of opinion

In conclusion I would say that we must continue with thoughts of conservatism and an open mind Great progress is being made in all phases of otology through laboratory and clinical research The progress being made in stapes mobilization surgery has been presented today

I thank the panel, the official discussers, the other discussers for their contributions today, and the audience for your kind attention

AMERICAN BOARD OF OTOLARYNGOLOGY

The American Board of Otolaryngology will conduct only one examination in 1958, and this will be October 6-9, 1958, in Chicago, Illinois, at the Palmer House

For further information address Dr Dean M Lierle, Secy-Treas , University Hospital, Iowa City, Iowa

extensive cases of otosclerosis I would like to make a plea for all of us to supply these gentlemen doing histological work with more and more specimens

Dr Goodhill confirmed our indications for the initial operation as presented two years ago There has been little change in these indications He stressed the necessity of unilateral masking to prevent the operation of stapes mobilization being done on unilateral perceptive deafness He pointed out the indications for revision He stated we are not in agreement regarding indications for revision The greatest help in this regard is to observe and make accurate detailed notes as to what was done at the initial operation Note at that time as to whether or not you feel a subsequent revision is indicated

Dr Shambaugh told us that the techniques have changed These changes include the use of the microscope, audiometry in the operating room, and more direct approaches to the footplate itself Both Lawrence and Shambaugh have stated that small perforations in the vestibule may improve hearing, but the lasting results of these procedures are questioned at this time He pointed out that the fenestration operation is predictive The frustration operation (stapes mobilization) is not predictive

Dr Kos told us that at Montreal this panel had operated approximately 1,100 cases Today this panel has operated 7,400 cases The results he reported average two months following surgery and he reported that 15 per cent of this group had subsequently regressed He mentioned that 49 per cent of our cases received improved hearing Of these 49 per cent who obtained improvement, 42 per cent reached the 30 db level or better It is the opinion of the panel that the incidence of regression is greater as we work more and more on the footplate

Dr Fowler stated that three per cent of the cases operated by this panel were worse, of which one-half of one per cent were severely worse Included in this series were three dead labyrinths that occurred following stapes mobilization He also mentioned that others have reported two deaths and one extradural abscess following this surgery had married the Democratic or Popular dictator, Marius, died, he said in the funeral oration

“On her mother’s side Julia descended from the ancient Kings, on her father’s from the Immortal Gods Themselves Her mother and my grandmother, Marcia, descended from Marcius the fourth King of Rome, while we of the Julian House trace back our origin to Venus herself In our family, therefore, we combine the Divine Right of Kings, who are the greatest among men, and the worship of the Gods, to Whose Power even Kings must bow”

Though obviously proud of his family and possibly not unmindful of his destiny, he was no idle boaster when it came to his own deeds as set out in his “War Commentaries” It could never be said, however, that he hid his light under a bushel, indeed, it would have been difficult so to do, as his great deeds would have shone out

In view of his noble origin, which included nearly all the Patricians, it might be thought that Julius Caesar would follow the Optimates, or Republican Party, which included nearly all the Patricians Instead he joined their opponents, the Populares, or Democratic party, to which the middle classes gave allegiance In this, no doubt, he was influenced by his uncle, Marius, who had been the leader of the Populares After the eclipse of Marius when Julius Caesar was a youth, Sulla, the champion of the Optimates, came to power and dealt very severely with his political opponents Fortunately for the Roman Empire, the young Julius was left alone, though he had to travel abroad for some time

Despite the great care taken to avoid any individual form of dictatorship in the Roman State it gradually came about that political power was concentrated into the hands of a comparatively small group of Patrician families who saw to it that they dominated the Senate Consequently, many of the laws which were passed favored the Patrician and land-owning classes Successful wars brought more slaves into Roman hands, and these slaves went to swell the estates of the landowners who were able to cultivate their land with cheap slave labor Thus the smaller farmers could not com-

JULIUS CAESAR AND THE FALLING SICKNESS*

TERENCE CAWTHORNE, F R C S ,

London, England

The idea for this paper came when, some years ago, I was re-reading Shakespeare's "Julius Caesar" at a time when I was preparing an article on Mènière's Disease In the very same scene, and separated by but a few lines, the following statements are made

Julius Caesar (who has been talking to Anthony about Cassius ends by saying) "Come on my right hand, for this ear is deaf"

Then shortly after, in a discussion about Caesar between Cassius, Casca and Brutus, the latter says

''Tis very like he hath the falling sickness"

Now it has always been assumed that Julius Caesar suffered from epilepsy, but unilateral deafness and the "falling sickness," I thought, could mean Mènière's Disease, so ever since then I have been inquiring into the life and times of Julius Caesar, with particular reference to his ailment

As the 2,000th anniversary of his death by assassination fell on March 15, of last year, it seems an appropriate time to discuss his disorder and to recall his remarkable career, which was brought to a brutal end by a determined band of his associates, many of whom he regarded as trusted friends Though he was the most powerful and the most popular man in the civilized world, and though it was freely admitted that he had done more for the glory of Rome than any other citizen, he had by his remarkable and versatile talents shown up the lack of ability in many others, earning the envy and malice of those around him whose ambitions were so much greater than their often meager abilities

A Patrician by birth, his was one of the oldest and noblest Roman families, the Julians, and when his aunt Julia, who

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*Read at the meeting of the Middle Section American Laryngological Rhinological and Otological Society Inc Philadelphia Pa Jan 9 1958

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reach this post, which has been described as a "carnival of illegality and mob law, which made a fitting close to the whole of his demagogic career "

Once his Consulship was over he took over the pro-Consulship of the Gallic Provinces, at the same time forming an uneasy alliance with the financier, Crassus, and the ex-soldier, Pompey This was known as the Triumvirate, and each was of equal Consular rank and power Caesar left for his Gallic Province, and it was 10 years before he returned to Rome, having in the meantime conquered the whole of Gaul, contained the Germanic hordes and invaded Britian twice

Despite his previously slight military experience, Julius Caesar soon proved to be an exceptional leader in war He was not only a great strategist and military tactician, but he was also a leader of men Many was the time that he, personally, led his men into battle, and he was often in the thickest of the fight As an orator and as a politician he was unequalled, and by sheer force of intellect he could persuade men to his way of thinking, equally well in committee, in the political arena and before a group of tired and even rebellious soldiers Even the eloquent though vacillating Cicero, the silver-tongued orator, was compelled to admit that he had met his master in Julius Caesar , but he never forgave Caesar for this, and I believe that it was he, Cicero, who was behind the plot to kill Caesar

At the end of the Gallic campaign Caesar fought his way back to Rome, from which his opponents, the Senate (headed by Pompey) had fled, and four more years of fighting in Spain, Greece, Africa and again Spain were needed before he finally returned triumphantly to Rome

During the year that was left to him he laid the foundation of a new autocracy headed by a Sovereign to rule the Roman Empire in the place of the Senate and the people His names have been immortalized in the month of July, and in the title of Caesar, Czar and Kaiser He forgave his political enemies, and this was his undoing, for they could not forgive him

As a young man he was undersized and delicate, but he grew up to be virile, tough and even licentious Though he pete with this cheap labor and sold their farms to seek their fortune in the Capital, adding to the number of the "hangers on" and unemployed

Successive political leaders vied with each other to gain popularity, and the increasing inefficiency and corruption of both parties were undermining the State, so that the time was ripe for a man with that rare combination of ambition and ability to rescue the Roman Republic from the slough of corruption and selfishness which was threatening to engulf it Though we know that Julius Caesar was the man to do this, it took him 50 years of pushing, bribing, intriguing and fighting to convince his contemporaries Even when he had succeeded, they could not forgive him, and despite all he had done for them and for the State, they murdered him, though they preferred to call it "tyrannicide"

This was a political blunder, for Caesar was the one man who could have built upon the old foundation, a solid and workable government His assassination involved the State in fresh struggles and civil wars, until in the end it fell under the supremacy of Caesar's heir and nephew, Augustus, who established a far more despotic rule than that which the so-called liberators had attempted to avert

Born in the year 102 B C, Caesar was, thanks to his uncle Marius' influence, given, of all things, a senior religious appointment as Flamen Dialis, at the age of 15 This gave him a seat in the Senate, but precluded him taking an active part in war or politics This did not last very long, and at 19 he went abroad, gaining experience in war as an aide-de-camp and as an orator and lawyer, from the leading teachers in the Grecian Islands This included an episode at the Court *of King Nicodemus, which later on was magnified by his* opponents into a homosexual scandal, however, his conduct in more mature years shows that if this incident ever occurred, it was but an adolescent prank, for Sir Charles Oman refers to him later as "the inevitable co-respondent in every fashionable divorce" Returning to public life in Rome at the age of 30, he achieved the coveted Consulship by the age of 42

He was not too particular about the means he employed to *are not perfect which have this disease of the falling evil, when standing on their feet they speak to the common people, but are soon troubled with a trembling of their body and a sudden dimness and giddiness*

It may be noted that in none of these three statements is there any reference to loss of consciousness, to foaming at the mouth, to twitching of the face or limbs, or indeed to any of the other manifestations of epilepsy

Plutarch, the Greek Philosopher and biographer, was born in the reign of Claudius half way through the first century, A D He wrote in Greek and his most famous work, his "Lives," compares and contrasts the Greek and Roman heroes His is the most contemporary and the fullest life of Caesar

There is another by Suetonius, the first in his series of "The Lives of the Caesars" This was written some 70 years after Plutarch Suetonius had the advantage of being Secretary to the Emperor Hadrian and in this position had access to Imperial Archives His "Life of Caesar," written in Latin, makes but one short reference to Julius Caesar's ailment "He was twice attacked by the *falling sickness* during his campaigns"

As might be expected, Caesar himself makes no reference to this sickness in any of his works, nor is it mentioned by Cicero, Lucan or Dio Cassius

Shakespeare's source of information about Julius Caesar came from Sir Thomas North's translation of "Plutarch's Lives", and it is Sir Thomas North who coined the term *"the falling sickness"* He did not translate direct from the Greek, but from the French of James Amyot, Bishop of Auxerre There is no mention in Plutarch, or in any other Greek or Roman author, of Caesar's being deaf, even in one ear

The only reference I can find of Julius Caesar's deafness comes from George Wherry, in "Notes and Queries (1909), Series 10, Vol XL, p 243

Julius Caesar's Deafness Shakespeare makes Julius Caesar deaf in the left ear To Mark Anthony, Caesar says "Come on my right hand for this ear is deaf," and his attacks of loved luxury and power, he never over-indulged in eating or drinking, and between the ages of 40 and 55 lived the hard life of a soldier on campaign Always in the public eye, any disorder, infirmity or even slight accident is sure to have been noted and even magnified We have heard of his baldness and of his amours, and even when he stumbled and fell when disembarking onto African soil during the Civil war this was noted by Plutarch I am sure that if he had been subject to real epileptic fits we would have heard much more about them than has come down to us from the writers of those times

Our main source of information about Caesar's "falling sickness" comes from "Plutarch's Lives," in which it is mentioned three times

The first was part of a general description of Caesar

He was lean, white and soft-skinned, and often subject to headache, and other while to the falling sickness, the which took him the first time, as is reported, in Cordoba

Now Caesar was three times in Spain The first time was before he was Consul, the second in the early stages of the Civil War before he defeated Pompey at Pharsalus, and finally after the African campaign, when he was dealing with Pompey's son and his followers This must refer to the second campaign in Spain, as Plutarch's next reference to the sickness is in the African campaign at the battle of Thapsacus against King Juba and Scipio When he did not take his usual place in the forefront of the battle Plutarch says

For as he did set his men in battle the falling sickness took him, whereunto he was given, and therefore feeling it coming, before he was overcome withal, he was carried into a castle not far from thence, where the battle was fought, and there took his rest till the extremity of his disease had left him

Plutarch's third reference is to the time when the populace offered Caesar the Emperor's crown and he refused it three times

Notwithstanding it is reported that afterwards, to excuse this folly, he imputed it to his disease, saying that their wits committee, ended the meeting Clearly such a description could include epilepsy, a stroke, a heart attack, and also an attack of Meniere's Disease

Now, as Caesar's mental and physical powers remained unimpaired between attacks, it seems unlikely that they were caused by heart disease or a cerebral catastrophe This leaves epilepsy and Meniere's Disease

When the "falling sickness" first overcame him, Caesar was in the early 50's, a common time for Meniere's Disease to start As the most famous man of the Ancient World, there was no shortage of writers and poets to publicize his failings as well as his strength Had he really suffered from epilepsy it is difficult to believe that it would have been passed over in the few words that have come down to us, nor can it be said that the Romans were unacquainted with epilepsy, for here is a description given by Lucretius of an epileptic fit

Oft times with violent fits a patient falls,
As if with thunder struck, and foams and bawls,
Talks madly, shakes, moves here and there, breathes short,
Extends and tires his limbs with antic sport,

* * * * * *

His weakness wears and he forgets his pain,
His strength, his life, his sense return again

Had Caesar suffered from major epileptic seizures, surely these sensational attacks would not have been passed over so slightly by the careful biographer Plutarch, or by the gossip Suetonius

Had these attacks been something more serious than a labyrinthine disturbance, they must have left a greater mark on the man who, for the last 15 years of his life extended and dominated the Roman State A man, moreover, who, at the end of 12 years' continuous fighting and political intrigue could take time off to share with Cleopatra one of the great love affairs of the world

That it could have been a minor form of epilepsy cannot be denied, though sufferers from "petit mal" so often are *epilepsy are also noted in the play "He hath the falling sickness" It is quite possible that attacks of giddiness, associated with Meniere's Disease of the ear, may have been mistaken for epilepsy The Romans were familiar enough with epilepsy, which they called "morbus comitialis," from the attacks witnessed in the Forum or Senate House, which broke up the Assembly, and it is unlikely that aural vertigo was understood at that time*

Where, then, did Shakespeare get his reference to Julius Caesar's being deaf in the left ear? It has been suggested that there might be some political significance in this, but it cannot be in the modern sense, for the term "Left Wing" and "Right Wing" became significant only in the Assembly of the French Revolution Again, could it be that Caesar was suggesting that he was going to forget what had just been said? But as he had just been doing all the talking and very little listening, there is little point in this suggestion As there does not appear to be any mention of Caesar's being deaf in any of the references available to Shakespeare, he may have put this in so as to add a touch of realism to the part We know that Shakespeare always made his great historical figures behave like ordinary human beings, and indeed, it is just that homely touch that makes his characters live It could well be that Shakespeare knew someone, or possibly more than one person, who was troubled with the "falling sickness" and deafness, and that he introduced the deafness in one ear in order to make Caesar like other men There is no reason to suppose that the deafness was brought in to help the stage business

Even if we deny Caesar's deafness on the grounds that we have only Shakespeare's word for it, we are still left with his "falling sickness" Plutarch, writing in Greek, refers to this as "Epileptikois," a term used in those days for any seizure that caused the sufferer to fall down and be helpless It is not surprising that many writers translated this as epilepsy, and so the term "falling sickness" and epilepsy have been loosely regarded as the same thing

Suetonius, writing in Latin, uses the term "morbus comitialis," the disease which, when it attacked a member of a

CASE OF TRACHEO-MALACIA FOLLOWING REMOVAL OF ADENOMA OF THYROID GLAND*

DEZSO KASSAY, M.D., (By Invitation),

Philadelphia, Pa.

A 50-year-old male, a dentist, had been complaining, for about six months, of a gradually increasing dyspnea and stridor. Bronchial asthma had been diagnosed in a hospital in Hungary.

On admission we found a well nourished man, 5'4" tall, and muscular; the patient's neck was extremely thick and short. On the left side of the neck a spherical resistance with a diameter of about 5 cm. could be palpated. This tumor moved up and down simultaneously with the swallowing action. The dyspnea appeared to be mild and the stridor audible only before the open mouth.

Planigraphy (see Fig. 2-A) showed the trachea displaced slightly to the right, and its lumen narrowed markedly from the left side by a protrusion 45 mm. in length. Tracheoscopy showed the tracheal lumen enormously stenosed by lateral compression. The mucosa appeared red and swollen, but no tumor tissue was noted. The biopsy and histologic study revealed only inflamed mucosal structure.

TRACHEAL STENOSIS DUE TO COMPRESSION BY ENLARGED THYROID GLAND WAS DIAGNOSED

At external operation (Rubanyi and Kassay) we found a soft, vascular, encapsulated tumor which was about 5 cm. in each dimension; resection of the tumor and trachectomy were performed. The tracheal cartilages on the left side for a length of about 45 mm. were destroyed, and the soft tracheal wall collapsed into the lumen. Adenoma of the thyroid gland was diagnosed histologically. Removal of the tumor did not

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*Read at the meeting of the Eastern Section, American Laryngological Rhinological and Otological Society, Inc., Philadelphia, Pa., Jan. 9, 1958.

Editor's Note: This manuscript received in The Laryngoscope Office and accepted for publication Feb. 27, 1958.

troubled also with bad tempers, fits of depression, or some form of neurosis; and there is nothing to suggest that Caesar was ever troubled in any of these ways. Coming on at that time of life and not leading to any deterioration of mental or physical powers it is, in the light of our present knowledge, much more likely to have been a benign disorder such as Menière's Disease.

We are still left with the problem of deafness, and though I have been unable to trace any contemporary account of Caesar's being deaf, I shall always be grateful to the memory of Shakespeare, not only for the plays which we enjoy, but for suggesting an alternative and to me, plausible cause for Caesar's "falling sickness."

ALUMNI ASSOCIATION OF THE NEW YORK EYE AND EAR INFIRMARY

The Annual Spring Meeting of the Alumni Association of the New York Eye and Ear Infirmary last April was so well received that it has been decided to expand next year's meeting, which will take place from April 20-23, 1959.

Symposia and lectures on Hearing Rehabilitation, Endoscopy, and Ear Surgery will be conducted. It is also planned to offer refresher courses in Mastoid and Fenestration Surgery and Stapes Mobilization Techniques.

More complete information regarding the meeting will appear in a later issue of THE LARYNGOSCOPE.

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by us, which would keep the tracheal lumen open and would not disturb him in his work.

Thus we designed a special tube for him which would hold itself in position, could be easily changed, occlude the stoma well and prevent the outflow or coughing out of tracheobronchial secretions Naturally we created first a longer stoma sewing the tracheal wall to the skin of the neck.

A metal tube (see Fig 1), with a 12 mm outside diameter was used Both ends were cut off obliquely, the anterior wall being longer than the posterior, which facilitated the introduction of the cannula The total length of the tube was 45 mm A screw was attached to the anterior wall, 12 mm from the upper edge of the tube A metal block, fitted precisely to the stoma and a wing-nut completed the instrument The block was 20 mm long and 11 mm wide, slightly less than the outside diameter of the tube, the depth of the block measured 14 mm on the top and 16 mm on the bottom At the proper point in the block, a hole was drilled for the screw The distance between the screw and the upper edge of the tube was shorter than the vertical diameter of the tracheal stoma

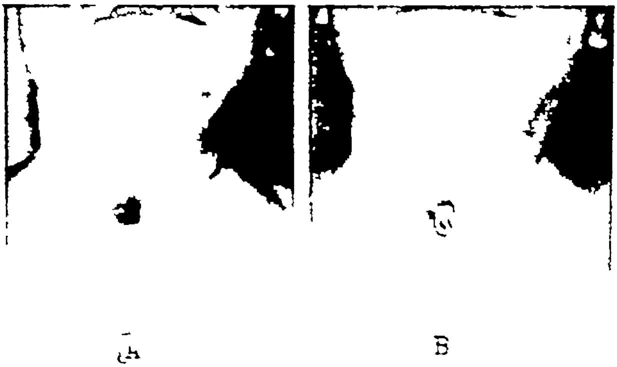

Fig 3 The open stoma (A) and the cannula in place (B)

At introduction the longer part of the cannula (below the screw) entered the trachea first until the screw touched the lower edge of the stoma, then the whole cannula was slid into

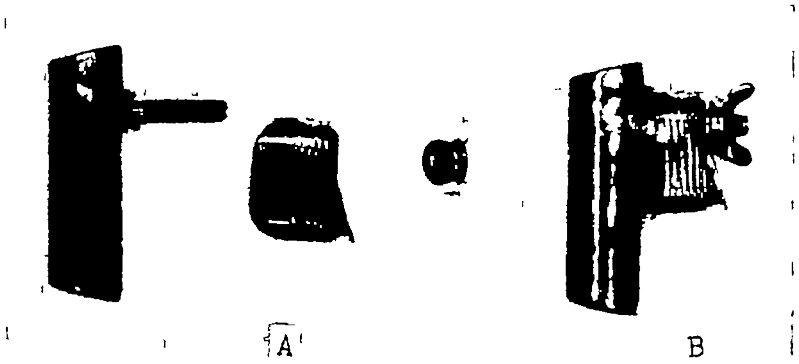

Fig 1 Parts of the cannula (A) and the assembled cannula (B)

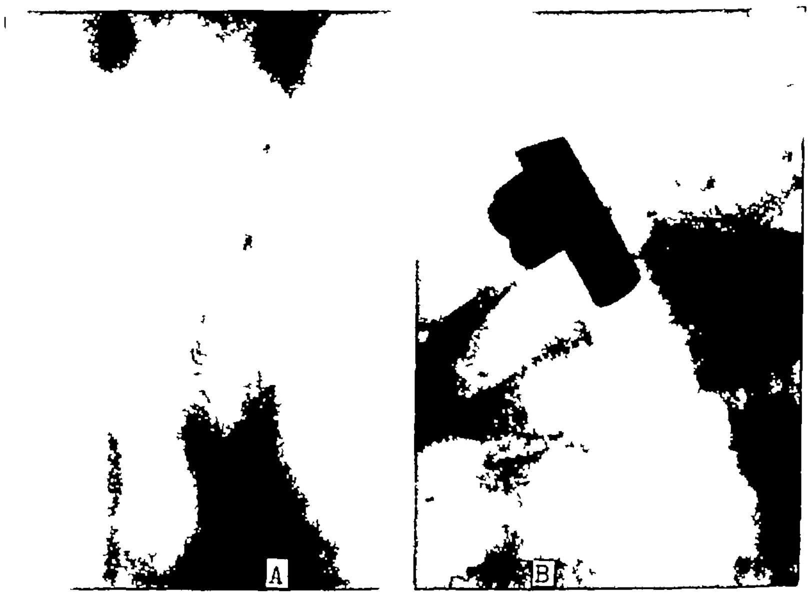

Fig 2 Planigraphy (A) shows the cervical trachea displaced slightly to the right and its lumen stenosed from the left side by external compression X-ray film (B) demonstrates the retaining cannula in place Note the wide lumen of the trachea

diminish the stenosis, this situation, checked repeatedly by tracheoscopy and planigraphy did not change for three months The patient refused resection of the tracheal portion, collapsed by tracheo-malacia, or any kind of surgical plastic repair, however, he was willing to wear a permanent tube suggested

SYMPOSIUM TYMPANOPLASTY

MODERATOR

F. A. SOOY, M.D., San Francisco, Calif.

PANEL

VICTOR GOODHILL, M.D., Los Angeles, Calif.
LELAND R. HOUSE, M.D., Los Angeles, Calif.
TERENCE CAWTHORNE, M.D., London, England

MODERATOR SOOY: First, I will introduce Dr. Victor Goodhill, who will talk to us on the principles of tympanoplasty.

THE SURGICAL PHYSIOLOGY OF TYMPANOPLASTY.*

VICTOR GOODHILL, M.D.,
Los Angeles, Calif.

INTRODUCTION

The term "tympanoplasty" has been applied to that group of surgical procedures in which the principles of reconstructive surgery are applied to the restoration of middle ear function.

For many decades, otologists have been aware of the necessity of such surgical reconstructions, and a number of attempts in this direction have been recorded. There are numerous instances of improvement in hearing following various forms of modified radical mastoid operations, but these occurrences were haphazard and usually not planned physiologically. No definitive methods and no techniques with predictability were available until the recent contributions of Wullstein,[1] Zollner,[2] Pietrantoni[3] and others.

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*Presented as part of a Symposium on Tympanoplasty at the meeting of the Western Section American Laryngological, Rhinological and Otological Society, Beverly Hills, Calif., March 4, 1958.

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the trachea and lifted, so that the upper portion of the tube entered the lowest part of the larynx The block was slid over the screw into the stoma and fixed in position by the nut (see Fig 2-B)

This procedure (the change of the cannula) was performed by the patient himself once or, when necessary, twice a day The cannula did not injure the tracheal and laryngeal tissues because it followed the movements of the trachea and larynx precisely and kept itself in position without being anchored by any mechanical means except that described above (see Fig 3) When I left Hungary, more than a year ago, the patient had worn his cannula for six months without any complaint

After this successful attempt I looked for similar solutions in medical publications, and found only one Jackson's bronchoscopy, esophagoscopy and gastroscopy, published in 1934 Their retaining intubation tube was used for treatment of chronic laryngeal stenosis The tube was introduced through the mouth, and then a post was screwed in through the tracheal stoma and a block was slid into the stoma Similarity of the two methods is the use of screw and block for keeping the cannula in place, in the larynx or trachea The difference is that the Jackson's introduced the tube by laryngoscopy, which could not be performed by the patient, himself, and thus it would not serve our purpose, however, essentially, we adapted an older method to a newer purpose, which may be expressed by the old Hungarian proverb "Read wise old books and create new things"

Lankenau Hospital

shielded from air-borne sound. An intact ossicular chain is necessary so that a significant sound pressure difference will exist between the two windows and thus between the two scalae allowing basilar membrane motion.

The Eustachian tube has an important function in maintaining essentially equal pressures on both sides of the tympanic membrane, thus avoiding painful stretching of the drum following ambient pressure changes in the external canal. This equalization allows maximum response under wide pressure changes.

It is of course possible for conductive lesions to reach db loss values far in excess of the 26 db described above as the contribution of the drum membrane and ossicular chain to sound pressure transformer action. In cases with intact drum but ossicular discontinuity, the drum may become worse than useless, since it may both reflect and absorb sound energy. Ankylosis of one of the windows may add another 25 to 30 db of loss to the function of the middle ear, thus conductive lesions may reach losses of 60 db and more. In extreme conditions, where scar tissue may simultaneously immobilize both the round window membrane and the stapedial footplate, it is conceivable that such an "acoustic short circuit" may even further increase the transmissive loss, although such a loss actually involves some perilymph immobilization, and may not truly be described as a middle ear lesion *per se*.

In addition to the above, there are problems of tympanic physiology which may involve the tympanic muscles as well as the suspensory ligaments of the ossicles. Such physiological problems will be reflected in the functional efficacy of the ossicular chain lever action, but in addition may produce increased stiffnesses and frictional problems resulting in varying deficits to acoustic transmission.

There are rather marked differences between the numerical values obtained in the human and in various experimental animals. Thus, much of the recent research data from cat and guinea pig studies are not so readily transferred to the human as had previously been considered possible. We must be alert to these major species differences in our interpreta-

At present, we are beginning to see the emergence of a positive plan of surgical attack with increasing predictability for restoration of tympanic function, however, we are still far from the time when results can approach the predictability of fenestration and even of stapes mobilization surgery

It is not surprising that the emergence of this branch of otologic surgery had to wait until the maturation of the principles of plastic and reconstructive surgery and the acquisition of fairly substantial knowledge of tympanic physiology The latter is still far from complete, but is adequate for practical application in many instances

It is the purpose of this presentation to correlate some of the known details of middle ear physiology and possible surgical approaches to the solution of tympanic problems Basic principles only will be presented Neither technical details nor results will be reported in this paper

BASIC TYMPANIC PHYSIOLOGY

The middle ear mechanism is essentially an impedance matching mechanism, or a "transformer" to help air-borne sound travel with increased force into the liquid perilymph with no significant alterations in frequency characteristics This is accomplished primarily by a combination of two physical mechanisms *1* the difference in area between the effective vibratory portion of the tympanic membrane and that of the stapedial footplate, *2* the lever action of the ossicular chain Contrary to some conceptions, it is primarily the area difference which is responsible for the sound pressure transformer action In man this is approximately 22 1 The lever action of the ossicular chain is approximately 1 1 1, and the product yields a result of approximately 26 db, which is the essential contribution of the entire middle ear mechanism to the transmission of air-borne sound to the cochlear perilymph, however, there are other factors in middle ear physiology which must be considered before one can understand the application of tympanoplastic procedures

The normal tympanic membrane is essentially transparent to sound waves, and thus the round window is not primarily solution, and many of them may be solved by tympanoplastic procedures The well recognized congenital defect of the external auditory canal, tympanic membrane and ossicular chain is best treated by a properly selected tympanoplastic procedure It is generally not recognized, however, that there are a number of congenital defects of the middle ear which may present themselves with normal tympanic membranes These lesions may include not only anomalies of the malleus, incus and stapes, but also congenital fixation of the footplate They are frequently accompanied by absent stapedius and tensor tympani muscles, as well as by deformities of the round window niche and even the promontory

TYMPANIC PHYSIOLOGIC PROBLEMS

1 Acoustic reception lesions
2 Acoustic transmission lesions
3 Window fixations
4 Loss of sound pressure difference
5 *Acoustic* short circuits
6 Multiple combinations of above

Fig 2

b Infections and Trauma

The most common group of lesions requiring tympanoplastic surgery are those produced by the sequelae of otitis media in which there may occur various combinations and degrees of disruption of the tympanic membrane-ossicular chain mechanism Similar lesions may follow both direct and indirect trauma to the ear

c Cholesteatoma and Other Ear Tumors

The most common space occupying lesion of the middle ear is cholesteatoma, of which there are a number of varieties Here again the dissolution of continuity of the middle ear mechanism is best treated by tympanoplastic surgical principles

LESIONS REQUIRING TYMPANOPLASTY—THE FUNCTIONAL STATES

The functional lesions that may disturb middle ear physiol-tions of experimental data obtained in lower animal forms, and extrapolated for human application

In summary, normal tympanic or middle ear physiology demands the existence of a patent external auditory canal (see Fig 1), a normal receptor mechanism via a normally functioning tympanic membrane, continuity of the tympanic membrane and a normally functioning ossicular chain, with a mobile stapedial footplate, a normally yielding round window membrane, and finally a well regulated tympanic air space provided by normal Eustachian tube function In the absence of a functioning ossicular chain it is necessary for the round window also to be shielded)

TYMPANIC FUNCTION REQUISITES

1 Patent external canal
2 Normal drum (pick up)
3 Intact continuity of drum, ossicular chain and mobile footplate (transmission piston)
4 Yielding but shielded round window membrane (sound pressure difference in absence of ossicular chain)
5 Tympanic air space equalization by normal tubal function

Fig 1

Obviously, not all of these requirements can be satisfied in every tympanoplastic procedure, and many compromises are necessary in the application of tympanoplastic surgical principles to the solution of middle ear infections, congenital defects, and other lesions, furthermore, the evaluation of a given conductive loss requires a very careful analysis of all possible contributing factors from all regions of the tympanic mechanism

LESIONS REQUIRING TYMPANOPLASTY—THE PATHOLOGIC STATES

A number of conditions involving the middle ear may respond to tympanoplastic maneuvers They may be simply divided into the three groups, *a* congenital lesions, *b* infections and trauma, and *c* cholesteatoma and other ear tumors

a *Congenital Lesions*

A number of congenital anomalies present themselves for lear reserve It is of little value to subject a patient to a major reconstructive procedure or procedures, to attempt restoration of tympanic function in the presence of a lesion of the cochlea sufficiently great to thwart a possible significant restoration of hearing, therefore, a careful assessment of the integrity of cochlear reserve is the first necessary preoperative physiological study This can usually be done adequately by pure tone audiometry with quantitative masking for bone conduction thresholds, speech reception thresholds and speech discrimination scores In some instances, recruitment studies may be indicated, but usually these are not necessary The demonstration of an adequate air bone gap (at least 15 to 20 db), a bone conduction threshold not lower than 45 db and a speech discrimination score not lower than 50 per cent are necessary pre-requisites

PRE-OPERATIVE TYMPANIC FUNCTION TESTS

1 *Cochlear Reserve and Bone Air Gap Tests*
  A Pure tone audiometry (A C and B C)
  B Quantitative masking for bone conduction
  C Speech reception threshold
  D Speech discrimination scores
  E (Recruitment tests)
2 *Prostheses Tests*
  A. Drum covering
  B Columellization
  C Blocking
3 *Acoustic Probe Tests*
  A Mechanical (Pohlman) probe
  B Audiometric B C vibrator probe

Fig 3

With demonstration of good cochlear reserve, the next function of preoperative testing is an attempt to gather qualitative, as well as quantitative, differential audiologic data regarding the status of the various middle ear components This requires a number of techniques (see Fig 3), which may be tailored to suit the individual case The following are the basic procedures usually necessary in most cases *a The drum covering prosthesis* This is simply a patch applied over ogy (see Fig 2), may be divided into the following groups *a Acoustic reception lesions* involving the sound pick-up action of the drum membrane, and most commonly produced by perforations of varying sizes and locations In accordance with the well-known studies of Békésy[4] and others, there are major differences in the sequelae of perforations, depending upon their size and location in relation to the manubrium and to the annulus, *b Acoustic transmission lesions,* involving the ossicular chain These lesions may involve any of the three ossicles in whole or in part They may be manifested not only by loss of continuity, the most common example of which is the aseptic necrosis of the lenticular process of the incus, but also by increased stiffness states involving the ossicular joints through arthritic fixations Occasional atrophic elasticity of incus or stapes crura may decrease transmission,

c Fixation of windows, especially the oval window, by ankylosis of the footplate and occasionally osteogenic closure of the round window niche and effective blocking of the round window membrane *d Loss of the normal difference in sound pressures delivered to the two windows* There is normally an effective difference in force of the sound pressures reaching the two windows Usually, of course, this occurs through the trans-ossicular excitation of the footplate in the oval window and through some minor blocking of air-borne sound to the round window by the curtain action of the tympanic membrane In situations where there is a loss of ossicular continuity, there may be an equal sound pressure level reaching both windows, which will decrease the possibility of basilar membrane motion, *e Acoustic short circuit* between the two windows by the effect of a scar tissue band running between the footplate and in contact with the round window membrane, *f Multiple combinations* of any of the above lesions, and also combined with some degree of perilymph immobilization by chronic labyrinthitis

PRE-OPERATIVE ASSESSMENT TECHNIQUES

In one crucial respect, tympanoplastic surgery requires the same pre-requisite as fenestration and stapes mobilization surgery, namely, in the measurement and evaluation of coch-

The electro-acoustic or audiometric B C probe type of test yields similar qualitative data, but also yields quantitative information for more precise comparison of tympanic responses, as illustrated in Figs 4 to 9 At present, it is not possible to establish an accurate base line for "normal" responses, since there are major variables in the pressure of application, size of applicator, etc , however, the comparative data obtained are most informative, and such careful tympanic exploration will frequently be of decisive character in planning tympanoplastic approaches

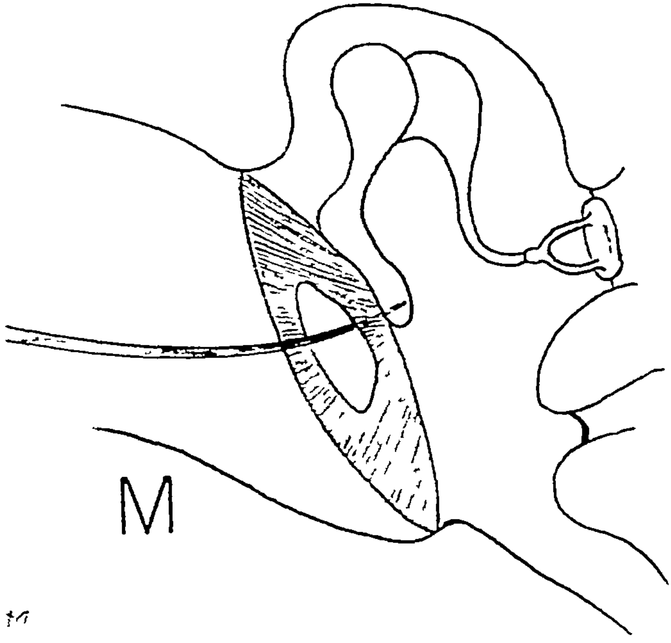

Fig 5 Probe in Contact with Malleus

The combined evaluation of data obtained by all of the above methods is invaluable in localizing the location and extent of middle ear lesions and in planning appropriate tympanoplastic solutions for these problems a perforation to increase the area of sound reception In the presence of an intact ossicular chain with no other obstructive lesions, such a test will usually reveal a significant improvement in hearing, *b A columellization prosthesis,* a capsule or Korojel (Pohlman) type of prosthesis applied to the incudostapedial joint, or to the capitulum of the stapes, will usually yield information regarding the status of the oval window in cases of suspected ossicular discontinuity or footplate fixation, *c Blocking prosthesis,* a similar capsule or Korojel (Pohlman) type prosthesis, or cotton oil plug applied to the

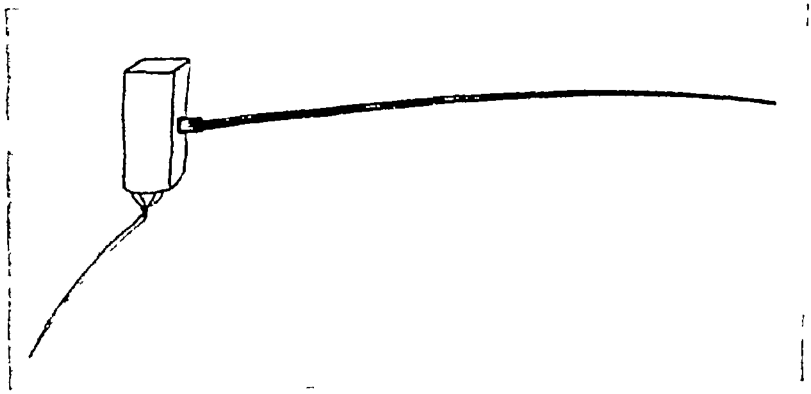

Fig 4 Electro-Acoustic Probe

region of the round window niche as a blocking prosthesis will give information regarding the sound pressure differences of the two windows, *d Probe audiometry* is of tremendous value in quantitative as well as qualitative estimation of integrity of the ossicular chain and the windows There is divided opinion as to the necessity of using probe audiometry in surgery, but its utilization diagnostically is conceded to be important by most workers in the field

Probe audiometry has been in use for a number of years after its introduction and popularization by the late A G Pohlman[5] His probe was a simple mechanical rod attached to a vibrating plastic membrane This mechanical probe test yields valuable differential tympanic information of qualitative nature middle ear scarring with not only obliteration of the air space, but partial immobilization of the stapes by a "blanket" of thickened mucoperiosteum In these cases there is justification for tympanolysis alone without any of the tympanoplastic procedures listed below

Tympanolysis can be divided into an anterior and posterior type In some instances it is necessary to use only the one approach, and in others both approaches are indicated

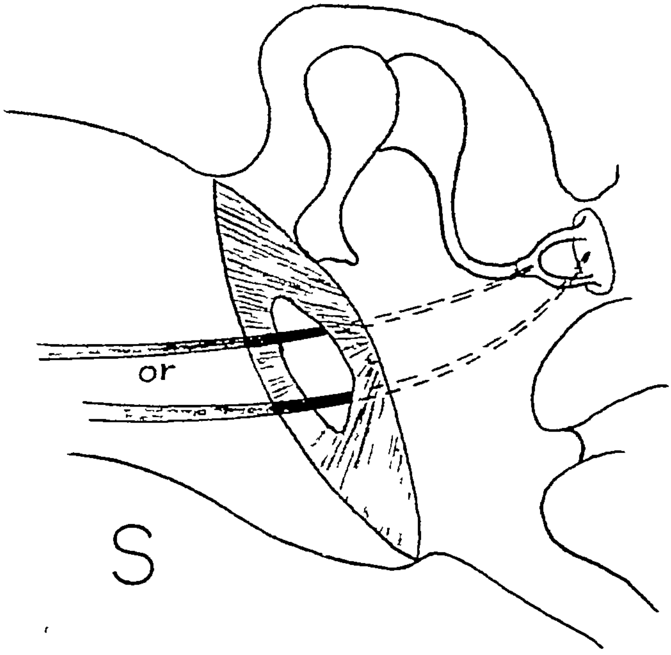

Fig 7 Probe in Contact with Either Stapes Capitulum or Footplate

Posterior tympanolysis is the most common type required, and can be accomplished by an exploratory tympanotomy, utilizing the typical stapes mobilization middle ear incisions in which the posterior one-third to one-half of the middle ear is adequately exposed (see Fig 10), and scar tissue lesions can be removed (see Figs 11, 12) In instances where clin-

BASIC TYMPANOPLASTIC OPERATIONS

The basic surgical approaches for restitution of middle ear function may be described under the two heads of, *a* Tympanolysis, and *b* Tympanoplasty

a *Tympanolysis*

This term applies to the surgical treatment of scars and fibrous tissue masses partially or completely immobilizing an otherwise normal drum membrane and ossicular chain (In addition, there is the necessity for removal of such scar tissue bands in many of the tympanoplastic procedures listed below) There are many cases of conductive deafness with intact drum membranes and anatomically and physiologically intact ossicular chains Here the entire problem is that of

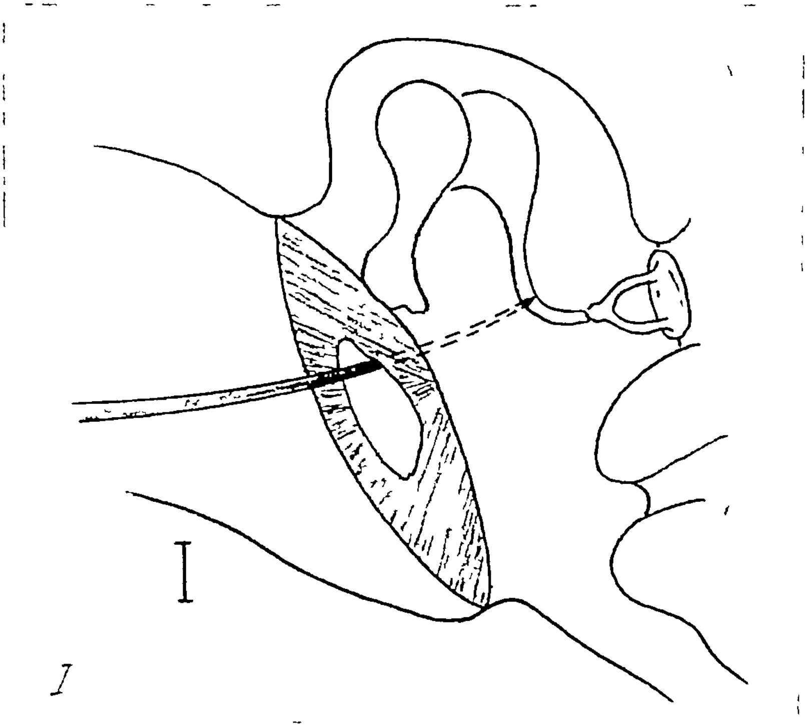

Fig 6 Probe in Contact with Incus

b Tympanoplasty

Wullstein made an excellent contribution to progress in this branch of surgery by giving us his schema, in which he presents five types of tympanoplasty based upon anatomical and pathological findings Since these five types have been widely adopted and have simplified discussions, it appears logical to utilize them in this presentation In the following tables and charts, the designations "Tympanoplasty Types I, II, III, IV, and V" will apply to the Wullstein classification to be given below

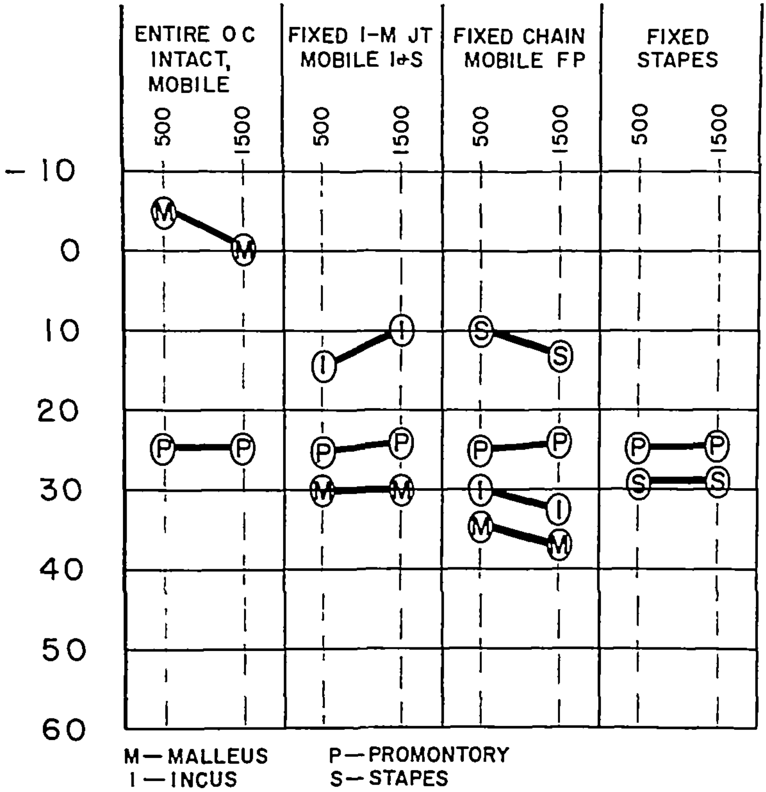

Fig 9 Representative Probe Audiograms

ical as well as operative findings in a posterior tympanolysis indicate a lesion anteriorly, an anterior tympanolysis is then performed This involves a triangular incision of the tympanic membrane as illustrated in Fig 13, in which the anterior portion of the tympanic cavity is exposed, particularly in relation to the Eustachian tube orifice After the exposure has been made (see Fig 14), appropriate instrumentation is performed for scar removal and the incision closed In the closure, occasional middle ear support for the flap is necessary with one or two pieces of gelfoam Occasionally a small skin graft is indicated to cover any anterior defect produced by retraction of fibers of the fibrous layer of the tympanic membrane

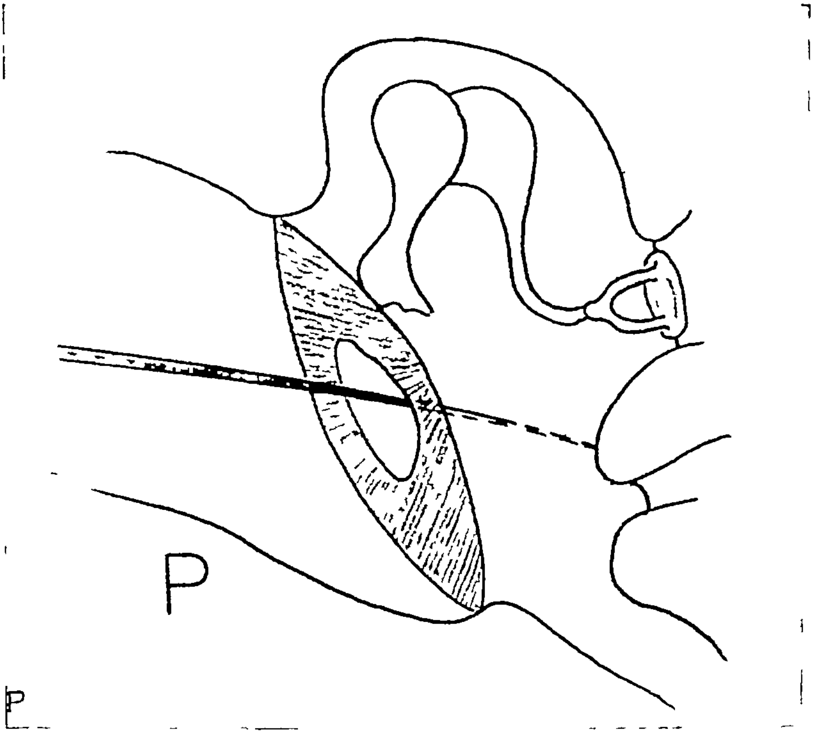

Fig 8 Probe in Contact with Promontory

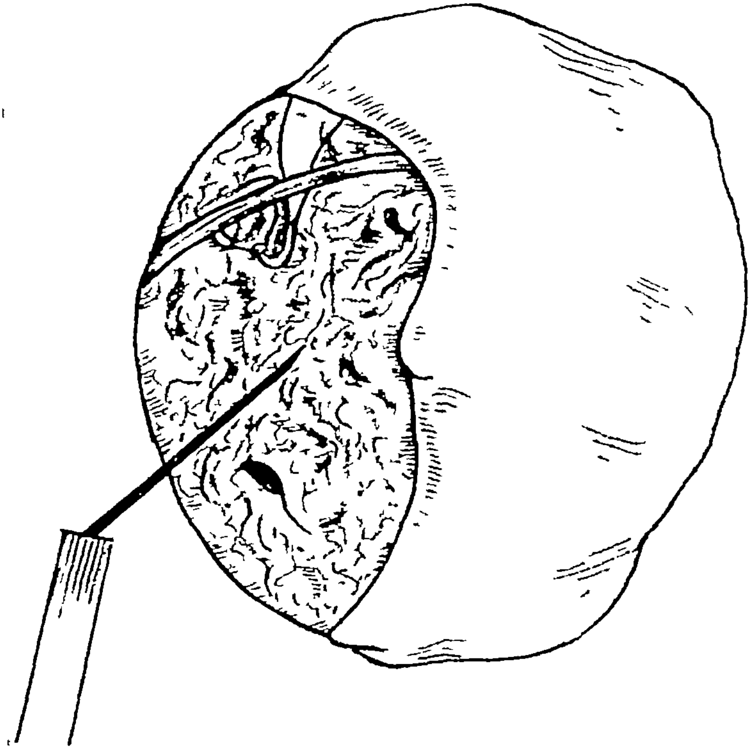

Fig 11 Posterior Tympanolysis with Removal of Diffuse Posterior Scars

procedure involving only the repair of the acoustic receptor, so that the area difference between the drum and the stapedial footplate may be restored, thus restoring the sound pressure transformer action

Type III (Columellization Operation or Myringostapediopexy)

In this very important type of procedure applied to cases where there is dissolution of continuity of function of malleus and incus, but normal anatomical and physiological integrity

Type I (Myringoplasty)

This is the simplest problem to solve surgically in tympanoplasty It refers to the closure of a perforation in the drum where there is an intact normally mobile ossicular chain and there are no other significant pathologic findings (see Fig 15)

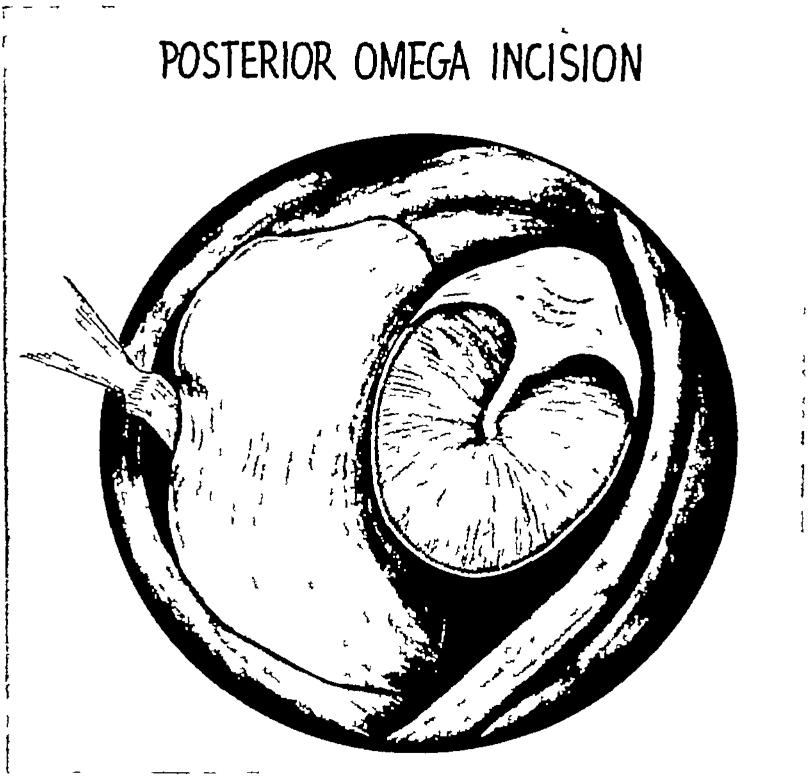

Fig 10 Posterior Omega Incision

Type II (Myringoplasty)

In this more advanced version of myringoplasty, there may be absence of a portion of the malleus or incus (see Fig 16), but there is still physiological continuity of the entire ossicular chain in spite of these defects This may be termed an expanded myringoplasty, but basically it is the same sort of

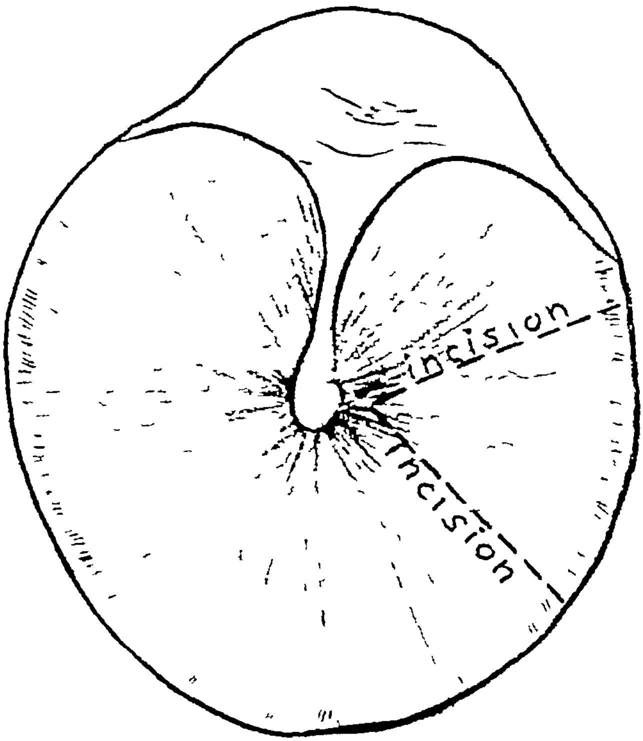

Fig 13 Anterior Tympanolysis Incisions

is still maintained, and the sound pressure transformation can be restored to a very efficacious degree, notwithstanding the loss of the lever action of the malleus and incus

Type IV (The Cavum Minor Operation or Sound Baffle Operation or Round Window Operation)

In instances where there has been a loss of stapedial capitulum and crura, but where the footplate is still mobile, the creation of the Cavum minor, or closed hypotympanum, may yield sufficient sound protection to the round window mem-

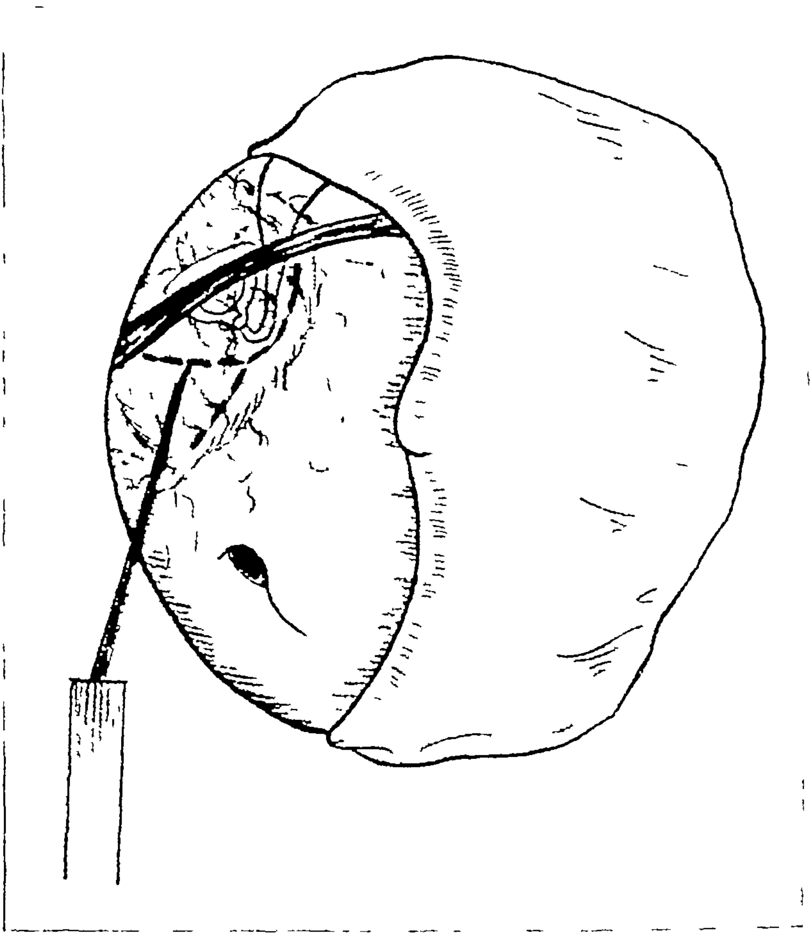

Fig 12 Posterior Tympanolysis with Dissection of Peri-stapedial Fibrous Tent.

of the stapes and the stapes footplate, a graft is applied directly to the head of the stapes (see Fig 17) This may either be done in cases where there is still a serviceable peripheral tympanic membrane remnant, or in instances where there is no tympanic membrane at all, as in post radical mastoidectomy cases In the latter instance a larger and thicker graft may be necessary, but the basic principle remains the same, namely, that the tympanic membrane (either restored or recreated) is anchored directly to the head of the stapes In this approach, the piston action of the drum to the stapes footplate the sound pressure difference may be adequate for sign gains in hearing

Type V The Fenestration Operation Combined with the Cavum Minor Operation

In instances where there is a fixed stapedial footplate there may still be hope for restoration of hearing by an adequate

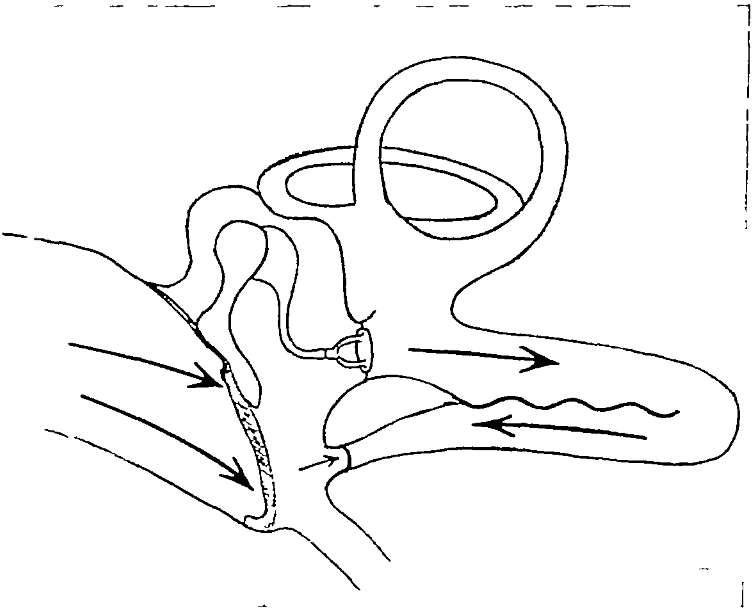

Fig 15 Type I—Tympanoplasty (Myringoplasty) Note normal ossicular chain with graft covering drum perforation

round window baffle procedure as described above, combined with fenestration of the horizontal semicircular canal, again yielding a level of possibly 30 db or better in some instances (see Fig 19)

(In certain instances where it is possible to mobilize the footplate with ease, one may combine a stapes mobilization with a Type IV, instead of resorting to a fenestration)

The approach to Types I, II, III, and IV tympanoplasty may

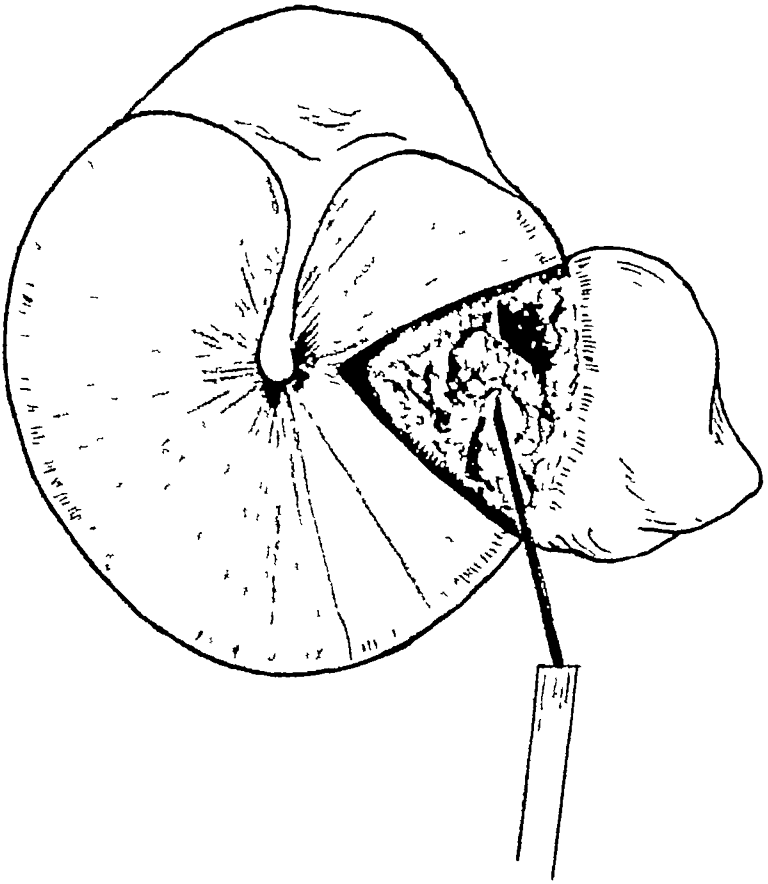

Fig 14 Anterior Tympanolysis with Dissection of Peri-tubal Fibrous Tissue

brane so as to restore the sound pressure difference between the two windows (see Fig 18-A) In this procedure, a mucosal graft is rotated inferiorly from the promontory over the round window niche and covered with a skin graft in continuity with the Eustachian orifice, thus creating a small middle ear which has tubal continuity and in which the oval window region is exteriorized to air-bone sound (see Fig 18-B) The round window acoustic baffle effect will frequently allow restoration of thresholds to the 30 db level The obvious loss of the transformer action of the middle ear still exists, but

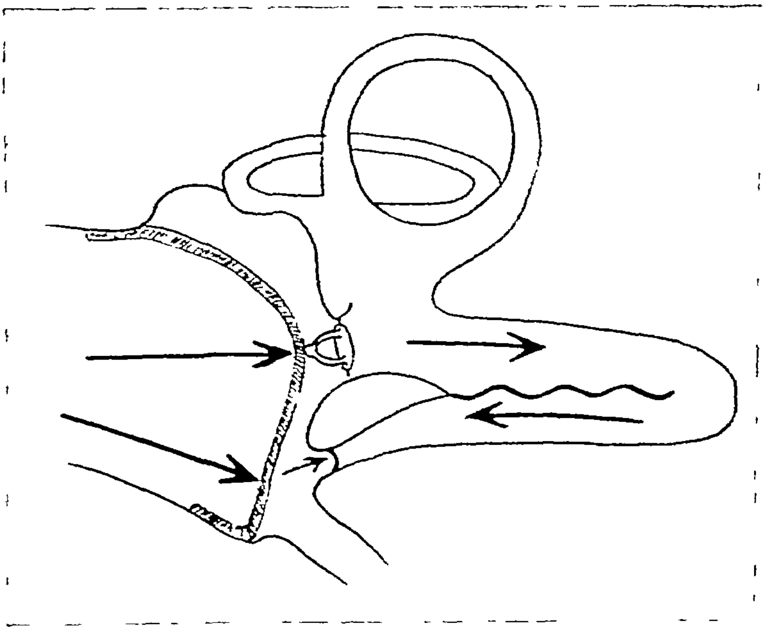

Fig 17 Type III—Tympanoplasty (Columellization or Myringostapediopexy) Note absence of malleus and incus Graft covers perforation and is in contact with stapedial capitulum

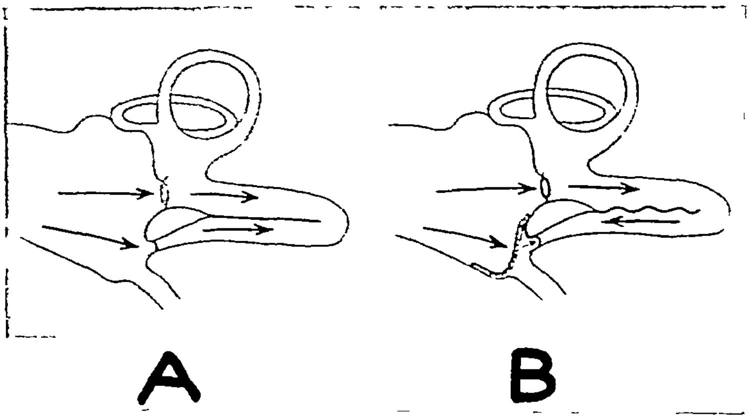

Fig 18 Type IV—Tympanoplasty (Cavum Minor or Sound Baffle or Round Window Operation) A Note loss of stapedial crura but mobile footplate Nevertheless because of lack of sound pressure difference the basilar membrane does not move B Creation of cavum minor blocks the round window membrane and re establishes a sound pressure difference. Note basilar membrane in motion

be either transmeatal or transmastoid The transmastoid approach varies quite a bit as to route of entry, thus the post-auricular, supra-auricular, and endaural approaches are all in use at the present time Type V tympanoplasty cannot be done transmeatally, since it involves a fenestration and must always be done through a transmastoid approach

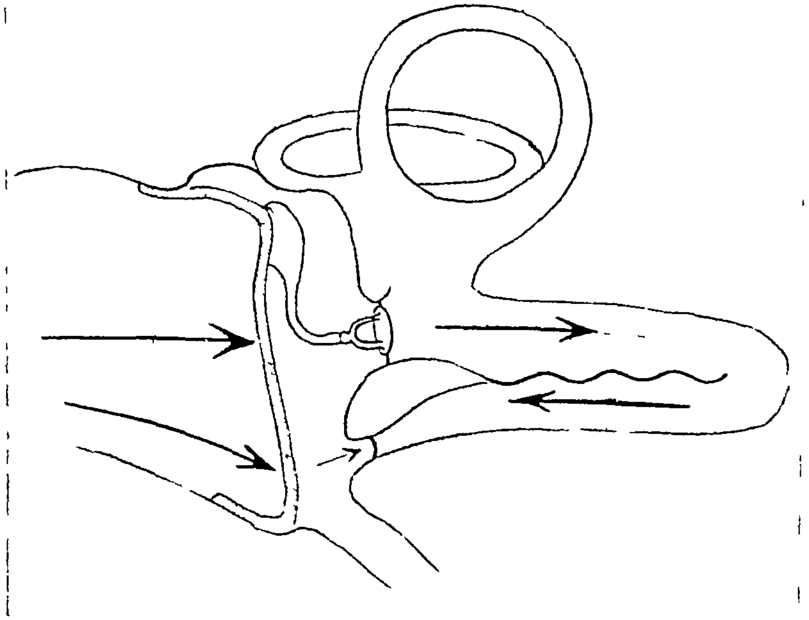

Fig 16 Type II—Tympanoplasty (Expanded Myringoplasty) Note absence of malleus with skin graft covering perforation and in contact with incus

SURGICAL AUDIOMETRY

At the present time there is no uniformity of practice with regard to surgical audiometry in tympanoplasty Some otologists prefer to do this type of surgery under local anesthesia with great reliance upon surgical audiometry, while others feel that the audiometric information obtained pre-operatively is adequate, and that the observations under the dissecting microscope fulfill the necessary criteria for decisions and, therefore, they do their procedures under general anesthesia gap apply just as forcefully to tympanoplasty as they do to stapes mobilization surgery

REPRESENTATIVE MIDDLE EAR PROBLEMS AND THEIR TYMPANOPLASTIC SOLUTIONS

Scores of pathologic possibilities may present themselves to the otologist for solution In an attempt to classify some of these problems, the following table (see Fig 20), was devised It lists a number of possible combinations of lesions, all of which have been encountered by the writer It must be remembered that all of these conditions may exist, either alone or in combination with some degree of mastoid disease Accordingly, the solution of these problems may be approached either through tympanotomy alone or through a combination of tympanotomy and mastoidectomy Thus, almost 80 possibilities may be considered in this tabular presentation Actually, the number of possibilities is infinitely greater when one considers the various combinations and cross combinations that may be encountered

EVALUATION OF RESULTS

It is not the purpose of this presentation to discuss results, except to point out that the evaluation of surgical results in this surgery should be no different from the method of evaluating the results of any type of middle ear surgery, including stapes mobilization and fenestration surgery As the author and his associates have pointed out in the past, and as has been pointed out by others, the only valid method of assessing *efficacy of surgical technique* in middle ear surgery is in the measurement of the degree of closure of the air-bone gap This evaluation technique must be considered, notwithstanding the practical aspect of the restoration of hearing to economic and socially desirable levels, (usually the 30 db level) We are all agreed that the latter is an extremely important final goal, however, when we are in the early stages of development of a branch of middle ear surgery, and are anxious to evaluate varying techniques and approaches, no method of evaluation other than that involving the degree of closure of the air-bone gap can yield any valid data It

There probably is a place for both local and general anesthesia in this group of cases There may very well be problems which can be solved better by surgical audiometry in some instances than in others Further experience and reports of many observers will help to answer this question

Of the methods available for surgical audiometry, two seem to be of greatest importance *a* the utilization of acoustic probe audiometry as described previously and as illustrated in Fig 9, in which definitive information of various portions of the ossicular chain may be obtained, and *b* surgical audiometry utilizing a modified nomograph, as described by the author and his colleagues in stapes mobilization surgery The latter may be applied to tympanoplastic surgery in certain instances, since the basic principles of closure of the air-bone

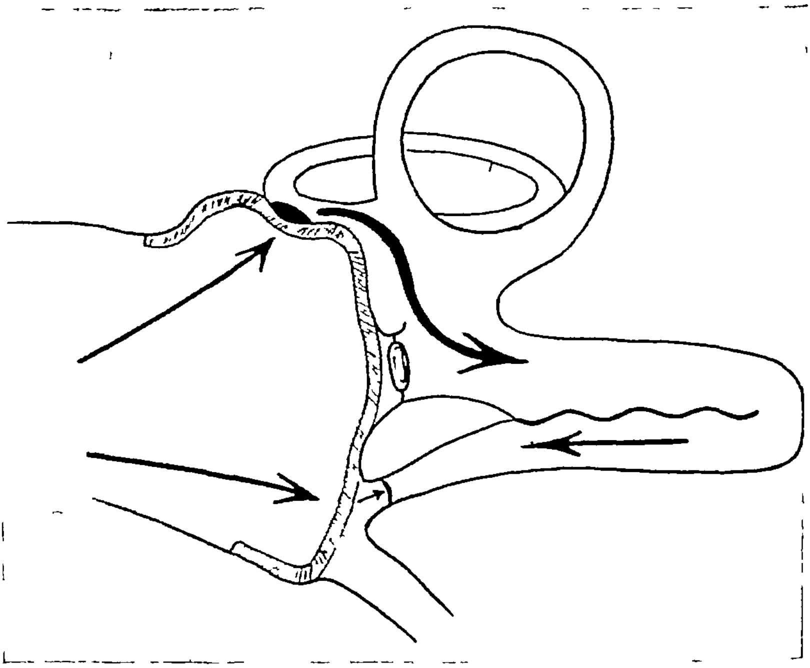

Fig 19 Type V—Tympanoplasty (Fenestration Combined with Cavum Minor) Note sound protection of round window and new entrance for sound through semicircular canal fenestra

M T perforation * * * Tymp fibrosis * * * Open E tube	20 40 db Post T lysis + T plasty I	20 40 db Post T lysis + T plasty II	30 60 db Post T lysis + T plasty III	30 60 db Post T lysis + T plasty IV	40 60 db Stapedolysis (P B) + Post T lysis + T plasty IV OR T plasty V
M T perforation * * * Tymp fibrosis * * * Closed E tube	25 45 db P & A T lysis + T plasty I	25 45 db P & A T lysis + T plasty II	30 60 db P & A T lysis + T plasty III	30 60 db P & A T lysis + T plasty IV	40 60 db Stapedolysis (P B) + P & A T lysis + T plasty IV OR T plasty V
No M T * * * No tymp fibrosis * * * Open E tube	Unlikely	Unlikely	30 55 db T plasty III	30 55 db T plasty IV	40 60 db Stapedolysis (P B) + T plasty IV OR T plasty V
No M T * * * Tymp fibrosis * * * Open E tube	Unlikely	Unlikely	30 55 db Post T lysis + T plasty III	30 55 db Post T lysis + T plasty IV	40 60 db Stapedolysis (P B) + Post T lysis + T plasty IV OR T plasty V
No M T * * * Tymp fibrosis * * * Closed E tube	Unlikely	Unlikely	35 60 db P & A T lysis + T plasty III	35 60 db P & A T lysis + T plasty IV	40 60 db Stapedolysis (P B) + P & A T lysis + T plasty IV OR T plasty V

Fig 20 Table showing the possible pathologic lesions the accompanying hearing losses and the recommended reconstruction techniques

Abbreviations—M T Membrana Tympani Tymp Tympanic E tube Eustachian tube T plasty Tympanoplasty T lysis Tympanolysis P B Peribasal P & A Posterior and Anterior

	Ossicles Normal and Normal Function of Ossicular Chain	Minor Malleus or Incus Lesions but Normal Function of Ossicular Chain	Defective Ossicular Chain but Normal Stapes	Defective Stapes but Normal Function of Footplate	Fixed Stapes Footplate
M T intact and scarred * * * No tymp fibrosis * * * Open E tube	0 10 db No Rx	0 10 db No Rx	30 50 db T plasty III	30 50 db T plasty IV	45 60 db Stapedolysis (P B) + T plasty IV OR T plasty V
M T intact and scarred * * * Tymp fibrosis * * * Open E tube	15-35 db Post T lysis	15-35 db Post T lysis	35 65 db Post T lysis + T plasty III	35 65 db Post T lysis + T plasty IV	45 65 db Post T lysis + Stapedolysis (P B) + T plasty IV OR T plasty V
M T intact and scarred * * * Tymp fibrosis * * * Closed E tube	15 40 db P & A T lysis	15 45 db P & A T lysis	35 65 db P & A T lysis + T plasty III	35 65 db P & A. T lysis + T plasty IV	45 65 db P & A T lysis + Stapedolysis (P B) + T plasty IV OR T plasty V
M T perforation * * * No tymp fibrosis * * * Open E tube	15 25 db T plasty I	15 25 db T plasty II	30 55 db T plasty III	30 60 db T plasty IV	35 60 db Stapedolysis (P B) + T plasty IV OR T plasty V

4 BÉKÉSY G VON Zur Physik des Mittelohres und über das Hören bei fehlerhaftem Trommelfell *Akust Zeitschr* 1 13 23 Sept. 1936

5 POHLMAN A. G The Mechanics of the Middle Ear Prosthesis *Ann Otol., Rhinol and Laryngol* 43 351 June 1936

MODERATOR SOOY I am sure I speak for all of us when I say how grateful we are to Dr Goodhill for giving us this excellent paper The next paper has to do with the clinical experience in tympanoplasty It will be presented by Dr Leland House of Los Angeles

CLINICAL EXPERIENCES IN TYMPANOPLASTY [*]

Results in Sixty-One Cases [†]

LELAND R HOUSE, M D ,

Los Angeles, Calif

Since "Plastic Surgery" means repair or reconstruction of a part, I have chosen to include any procedure which is done to repair or reconstruct any of the tympanic structures within the subject of "tympanoplasty "

This would then include surgical repair of simple perforations of the tympanic membrane alone, or combined with any changes in the ossicles and middle ear membranes and windows for the purpose of eradicating disease, and/or preserving or restoring hearing Various names are appropriately applied to more specific procedures, such as myringoplasty, transmeatal tympanoplasty (Bell), myringostapediopexy (Juers), tympanomalleolar stapedopexy (Bell), endaural tympanoplasty, and others

It seems appropriate to include all of these procedures in our general thinking on the subject of tympanoplasty, but time and experience plus usage will encourage the use of more specifically identifying terms Time will not permit elaboration on each type of the above mentioned procedures In

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[†] Department of Otolaryngology College of Medical Evangelists

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is the feeling of the author that the per cent improvement technique which we have previously described in stapes mobilization surgery, should also be used in the evaluation of results in tympanoplastic surgery This per cent improvement technique is easily arrived at by dividing the decibel gain post-operatively by the air-bone gap

$$\text{Per cent Improvement} = \frac{\text{A C Gain (db)}}{\text{B C A C Gap (db)}}$$

SUMMARY AND CONCLUSIONS

1 Basic physiological principles underlying tympanoplastic surgery are presented Pre-operative and operative evaluative techniques are described, and the multiple possibilities of tympanoplastic approaches are tabulated

2 A methodology for evaluation of results is presented involving the per cent improvement technique, based upon degree of closure of the air-bone gap

3 Tympanoplastic surgery is in a very early stage of development It is based largely upon the application of plastic surgical principles to recently acquired knowledge of tympanic physiology It is interesting to speculate on the increased knowledge of tympanic physiology which will accrue as the result of tympanoplastic surgery itself Never before has it been possible to acquire as much quantitative data under microscopic inspection conditions of the middle ear as during this present new era of tympanoplastic surgery

4 Tympanoplastic surgery must be based upon careful evaluation of the physiologic state of the middle ear in every patient No simplified rote operation can be used without such evaluation It is better to think of tympanoplasty as a surgical approach than as an operation *per se*

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3 PIETRANTONI, L , and BOCCA, E Functional Surgery of Chronic Otorrhea *Jour Laryngol and Otol* , 69 653 656, Oct , 1955

several cases One case was a boy 11 years old, in whom I did the Wullstein approach on one side and the endaural on the opposite side In my experience, postoperative care is a little easier through the meatus created by the endaural incision than by the postauricular incision One case which developed a localized perichondritis of the auricle around the tragus and antitragus occurred with the postauricular incision In some cases a limited procedure may be accomplished through the normal meatus without an external incision

Surgical Attack If pathology is obviously limited to the tympanic membrane, I do not elevate the membrane to inspect the middle ear nor open the antrum or attic In most cases, however, I am now following the plan of opening the mastoid antrum and the attic Complete removal of mastoid cells, or the removal of disease from around the ossicles, is done according to what pathology is found The posterior superior segment of the tympanic membrane is elevated from the annulus in most cases for inspection of the middle ear Continuity and mobility of the ossicular chain and middle ear windows is studied An effort is made to remove diseased polypoid mucosa, granulation tissue and cholesteatoma If this can be done without interrupting the intact ossicular chain the ossicles will be left The entire pars flaccida and the pars tensa may be removed without breaking the ossicular chain if indicated

If cholesteatoma or granulations completely surround the ossicles, or if disease has caused erosion, they will be removed In several cases the ossicular continuity had been destroyed by disease with fairly good preservation of the pars tensa In these cases the incus was removed, the head of the malleus was removed, and the remaining drum membrane was used to seal off the tympanic cavity below the oval window creating a small tympanum

Skin Grafts Grafts are used to replace or cover areas where the tympanic membrane has been damaged or removed The usual source is a free, full thickness graft from the postauricular area Tympanomeatal flaps or flaps from the canal preparation for this study, I have reviewed the surgical records of some 125 cases which have been done at the White Memorial Hospital during the last three years, including 61 which I have personally been able to follow in more detail

In general, we have followed the principles of Dr Wullstein and have followed his classification for the purpose of this study Many details, no doubt, have fallen short of the perfection which he has attained, because of our limited experience As I reviewed our cases I was impressed with my change in attitude toward temporal bone disease in the last few years In previous years the available procedures for the management of the diseases of the temporal bone resulting from infection consisted principally of the modified radical mastoidectomy and the radical mastoidectomy The question usually was, "Do we do a radical mastoidectomy or not?"

Thanks to the influence of Drs Juers, Baron, Zollner, Wullstein, and many others, our thinking has changed from surgery of destruction to that of restoration or preservation As evidenced by our results, there is much progress to be made I anticipated that our results might not justify any great sense of pride in accomplishment I do feel encouraged, however, to find that we have helped many of these patients in a manner that would not have been accomplished by our routine procedures a few years ago Now, instead of a cut-and-dried procedure, each case is a challenge, with its own particular problem to solve It is approached with the idea of doing whatever seems necessary to eradicate the disease and still conserve and reconstruct the hearing functions

I have studied 61 cases in quite detail and will review points of interest

Anesthesia By far the most cases were done under general endotrachial anesthesia There is no hesitancy to use local anesthesia when desirable, especially for the less extensive procedures

Incisions In most all cases I prefer the endaural incision I have not used the Heermann incision, as advocated by Zollner I have, however, used the postauricular approach on cases resulted in good healing with intact tympanic membranes, and five had a recurrence with a secondary perforation in the graft Nine had good hearing (above 30 db), two had poor hearing, and two had no record of postoperative hearing test

In this group, which admittedly is very small, I find no correlation in the incidence of the breaking down of the graft and the size of the original perforation Some of these had a repair of a limited localized perforation and others had the entire tympanic membrane replaced by a graft

Type II in this classification include those which have a slight defect involving the ossicles as well as the tympanic membrane The ossicular defect is such that the ossicular chain can still be considered functional in the repair I have included those cases in which granulations, cholesteatoma, or fibrous tissue was found in the attic or tympanum, but still could be removed without a major dislocation of the ossicles

TABLE II

TYPE II—22 Cases

Healing—	
Satisfactory	16
Perforations	6
Hearing—	
Incomplete Data	4
Not Improved	6
Slightly Improved	4
Good Hearing	8

In this group I reviewed 22 cases Sixteen of these had satisfactorily healed cavities This means that the graft is intact and apparently viable, and that the mastoid cavity is dry or free from suppuration with no more than a modest amount of crusting and debris Six developed secondary perforations in the graft, one of these was during an episode of re-infection after an intact membrane had remained healed for 18 months The audiometric data was incomplete in four cases, leaving 18 cases for hearing comparison Eight cases had good hearing (above 30 db average), and ten had poor wall may be used occasionally for small defects. Before applying the graft, all epithelium is removed from the recipient area to avoid burying epithelium. The promontory will be denuded in some cases to provide better source of nutrition for the graft. If the mastoid cavity is large, I prefer not to line the entire cavity with skin, but to allow it to granulate in and epithelize itself. So far I have not used delayed grafting.

To maintain separation of the graft from the middle ear mucosa, and to prevent obliteration of space, very small pieces of soaked gelfoam have been used in the hypotympanum, the Eustachian tube area and the round and oval window areas.

TABLE I

TYPE I—13 Cases

Healing—	
Satisfactory	8
Perforations	5
Hearing—	
Incomplete Data	2
Poor Hearing	2
Good Hearing	9

The physiologic demands necessary for preserving and restoring hearing have been well presented in former literature and reviewed by Dr. Goodhill. These requirements must be continually in mind when approaching each case.

For the purpose of discussing this series I will briefly summarize our cases from each group. Two factors were considered, the type of healing result and the comparison of preoperative and postoperative hearing.

Type I, as classified by Wullstein, includes those cases which have an intact and functioning ossicular chain and round window with some defect in the tympanic membrane. In these cases a successful repair will result in an essentially normal ear.

In this group, Type I, I reviewed 13 cases. Eight of these two there was no improvement, and the hearing remained at the preoperative level below 30 db

From a theoretical estimate there should have been a better percentage of good hearing cases in this group As near as I can determine, the chief cause for poor hearing was the reformation of adhesive processes with fixation of the flap and obliteration of the tympanic space This impaired the freedom of one or both of the two windows

Type IV are those cases in which the ossicular chain is entirely lost except for a mobile stapes footplate The ideal repair in these cases seems to be to create a small tympanum with a pneumatic space which communicates with the Eustachian tube and the round window The oval window niche is not covered at all with the graft, and is left open to receive air-transmitted sound pressure directly The round window is protected from direct sound pressure by the tympanic membrane This provides the phase differential that is necessary in hearing

TABLE III

TYPE III—10 Cases

Healing—	
Satisfactory	7
Perforation or Drainage	3
Hearing—	
Incomplete Data	1
Not Improved	2
Slightly Improved	4
Good Hearing	3

The small tympanum may be made ideally by the intact pars tensa if it has not been destroyed by disease In six cases I found this possible The ossicles were all destroyed, and the attic was diseased, but the pars tensa was sufficiently intact to use it to seal off the tympanic cavity just below the margin of the niche of the oval window If the pars tensa is inadequte to create this small tympanum, then a skin graft is applied in one piece to cover all of the tympanic area and extend upward to cover the attic. A small button hole is cut hearing Of those with poor hearing, four showed definite improvement, but were still below the 30 db level

There were three significant complications One was followed by a dead labyrinth A very large cholesteatoma had eroded a segment of both the posterior and horizontal canals On removing the mass of cholesteatoma, some of the endolymphatic labyrinth was pulled away About ten days after surgery this same patient developed a perichondritis Fortunately, this remained localized relatively well in the lower portion of the meatus near the tragus and antitragus, but was slow to clear The organism was pseudomonas which, of course, is resistant to most antibiotics, and in my experience is a trouble maker The postauricular approach had been used on this patient, but may not have had any bearing on this complication

Another patient developed a facial paralysis which at first was partial During the first week it became complete, but started to recover after the third week Recovery was slow, but was complete after 16 weeks

Type III cases are those in which there is a major defect in the ossicular chain requiring the removal of the incus and malleus, but preserving the stapes This leaves the capitulum protruding slightly above the level of the margins of the niche of the oval window The tympanic membrane or graft then is laid over the capitulum in contact with it The newly created tympanic membrane then lends sound pressure transmission directly to the stapes, this being spoken of as the columellar effect Because the graft lies close to the promontory and the pneumatic space of the middle ear is thereby made shallow, it is much easier for adhesions to form and obliterate the space

I reviewed 10 of these cases In seven the cavity was considered to have healed satisfactorily, in two small perforations recurred, and in one there was active secretion from an unhealed mastoid cavity Three cases had good hearing (above 30 decibel level) Four cases had distinct and useful improvement in hearing, but still below the 30 decibel level In this series one case with a fixed stapes footplate was included in my Group III above A mobilization of the footplate was done and the graft placed across the capitulum Hearing result was not good, further surgery is contemplated

I will summarize our findings in these 61 cases by combining the results of all of the types presented

TABLE V

SUMMARY—61 Cases

Healing—		
Satisfactory	46	75%
Perforations or Discharge	15	25%
Data Incomplete	8	
Hearing—		
		% of 53
Not Improved	13	25%
Slightly Improved	10	19%
Good Hearing	30	56%

Forty-six (or 75 4 per cent) were considered to have satisfactory healing with no perforations Fifteen had perforations or active discharge In eight the audiometric data was incomplete, leaving 53 cases for preoperative and postoperative hearing comparison Of the 53 cases, 30 (56 6 per cent) showed a hearing level above the 30 db loss in the speech range Eleven were improved but below 30 db Twelve were not improved

Admittedly, this is a relatively small series of cases and does not justify any fixed long range conclusions It does lend encouragement for further efforts in this field Time and experience may never solve all of the problems we face in this work It does seem that another new field of otology has been opened up and that many advances may be expected in the future

I am indebted to others on my staff who have allowed me to review their cases and assisted by giving me clinical and audiometric data Dr Emery Pick, who was the first to bring Wullstein's and Zollner's work to this city, has been especially helpful out of the graft corresponding to the oval window, leaving it uncovered Several cases in this group have given surprising results with hearing in the speech range averaging 18 to 22 db

The records of 16 patients of this type were studied In 15 cases the cavity and graft were considered to have healed satisfactorily and one developed a secondary perforation from re-infection Ten cases (62 per cent) had good hearing (above 30 db), two showed improvement, but below 30 db, and three showed poor hearing with no improvement

TABLE IV

TYPE IV—16 Cases

Healing—	
Satisfactory	15
Perforation	1
Hearing—	
Incomplete Data	1
Not Improved	3
Slightly Improved	2
Good Hearing	10

Percentage wise this group gave the best results of all groups, and Group III gave the worst Factors favoring Group IV are

First, only a small pneumatic space is needed, and this is in the region where the tympanic cavity is the deepest and most easy to preserve

Second, the short length of skin graft bridging from one point of contact to the next makes the nutrition of the graft less critical

Third, in these cases the greatest damage by the disease was in the attic with a relatively less severe change in the hypotympanum The skin graft is less likely to adhere to a normal mucous membrane surface

Wullstein's Type V are those which have a fixed stapes footplate In these cases a stapes mobilization or a fenestration must be combined with other procedures as indicated In

Though it has not been mentioned I do not doubt that our speakers advise using the Zeiss microscope for tympanoplasty Wullstein, himself, makes the point that his work consists of two things first, microscopic control in the eradication of infection, second, the restoration of function

Anyone who has seen Prof Wullstein will realize that tympanoplasty is not a set operation What is done depends upon what is found, and an operation may take several hours This is necessary in order that all infectious material is removed from the tympanic space before it is closed in by skin

I have always felt that the danger in tympanoplasty comes from burying sepsis under skin Wullstein and Zollner are fully aware of the danger of this, but I know from my own experience and from what I have seen of others that not everybody is so careful and painstaking in eradicating every little bit of pathology so that nothing is left behind One of my friends who is very keen on this work and whose opinion I value highly, said that for every ten cases in which he hoped to end up with a Wullstein Type II operation—that is to say, leaving the ossicular chain more or less intact—this happened only in three In the remainder, he had to remove the malleus and incus in order to eradicate the infection After what we have heard from Dr House today, it looks as though it might be a good idea to clip off the crura of the stapes as well

In stressing the importance of not burying sepsis under skin, I have in mind that our first duty to a patient with a chronic suppurative otitis media is to make that ear safe If we sacrifice that principle in the hope of saving or restoring hearing—laudable though the idea may be—then we are not doing our duty to the patient Infection and its ever present danger of spread intracranially, must be eradicated before starting to save or restore hearing

When it comes to the question of the skin graft, the speakers this morning, like Wullstein and Zollner, use full thickness skin taken from behind the ear Some workers are claiming good results when using split thickness grafts which they find are less irritating, and are more likely to survive than whole skin It is, however, maintained that the whole skin

MODERATOR SOOY Thank you, Dr House We will now have Dr Cawthorne's contribution to this Symposium

Summary and Remarks

TERENCE CAWTHORNE, M D (London, England) I still do not quite know why I was called on to summarize this discussion, because my experience and knowledge of tympanoplasty is very slight, however, I have learned a great deal from the discussion this morning

I think we all realize what a great debt we and the whole world owe to Prof Zollner and also to Prof Wullstein for their original work in this field, and for arousing our interest in the restoration of function where it was always assumed that it was not possible to restore function

Dr Goodhill mentioned the importance of the differential sound pressure, and we are indebted to Dr Wever and to Dr Lawrence for the clear explanation of this, which appears in their book "Physiological Acoustics"

Dr Goodhill also mentioned ankylosis of the stapes Now I cannot resist saying that it is not very often that the stapes becomes ankylosed in the true sense of the word "Ankylosis" and "fixation" as applied to a joint mean that the joint is fixed, that it won't move, I do not believe that in otosclerosis the stapes is often so fixed If it were, little or no sound would get through and the patient would be very deaf, indeed I think that usually it is impeded When it is really fixed, and I have under the microscope seen the stapes buried up to the neck in otosclerotic bone, that patient has had a 95 decibel loss in hearing Such a hearing loss does not necessarily indicate poor cochlear reserve I think that it is probably one of the physical effects of complete ankylosis of one or both windows, and that cochlear function may be unimpaired

With regard to the question of approach, I have always thought that one should be familiar with any of the three approaches to the middle ear posterior, endaural or endomeatal Only then is one really in the position to be able to choose the approach most suited to the operation charge granulations or cholesteatoma, a good functional result is not necessarily sacrificed by a thorough clearance of the middle ear including most of the ossicular chain.

PROGRAM OF THE SEVENTH INTERNATIONAL CONGRESS OF BRONCHOESOPHAGOLOGY

Meeting Place—Kyoto University, Kyoto, Japan

Friday, September 12th, 1958

8 00 P M -10 00 P M—Reception (Party) Shimomura House in Kyoto

Saturday, September 13th

8 00 A M—Inaugural Session (in Kyoto University Hall)

9 00 A.M -12 00 M—First Scientific Session

12 00 M -2 00 P M—Luncheon (Reception The Place not decided)

2 00 P M -6 00 P M—Sightseeing in Kyoto

8 00 P.M—Banquet, Miyako Hotel

Sunday, September 14th

8 00 A.M -11 30 A.M—Second Scientific Session

11 30 A M -12 00 M—Closing Ceremony

12 00 M—Departure for sightseeing in Nara

1 00 P M—Luncheon, Nara Hotel.

2 00 P M -6 00 P.M—Sightseeing in Nara

7 00 P M—Return to Kyoto

gives a better chance of maintaining an air space in the lower part of the tympanic cavity

Now this is very important, because for good hearing it is necessary to have an air space including the round window and the Eustachian tube but separated from the oval window Both Zollner and Wullstein lay great stress on this, and they start inflating the Eustachian tube soon after the operation

There is one other question which has not been mentioned yet which is of interest Should tympanoplasty be advised for unilateral ear disease or should it be reserved for bilateral cases? Probably when one is beginning it would be quite a good plan to start on unilateral cases, because failure to improve hearing would not be so disappointing for the patient

I have one final word about the Type I type of case, myringoplasty One of my colleagues, Stuart Mawson, has been doing quite a number of myringoplasties and has been getting remarkably good results He works through an endomeatral incision on ears with large perforations The ear must be dry and there must be no suggestion of any chronic disease within the attic The patient is laid up for a day or two at the most The perforation is covered with full thickness skin, and in a very large proportion of the cases, the perforation is permanently closed

Besides improving hearing it usually prevents the recurrent bouts of otitis media, which with large perforations so often follow on moisture getting into the ear This avoids having to take special care when swimming, having a shower or a hair shampoo

Finally, I was very interested to note that in the series just quoted by Dr Goodhill and his colleagues, their best functional results followed either myringoplasty or where the only part of the ossicular chain left as the footplate of the stapes (Wullstein Type I and Type IV), thus if the surgeon can satisfy himself that he is dealing only with a case of recurrent otitis media with a large central perforation, myringoplasty is a safe and functionally satisfactory operation Where the tympanic sepsis is persistent, and particularly when there is evidence of bone disease or erosion in the shape of foul dis-vocal process on each side. It appears as a grayish-white, sometimes red, wrinkled dry thickening of the mucosa.

Microscopically, keratosis is recognized by thickening of the epithelium, especially in the cornified stratum. As in leukoplakia, there may be evidence of chronic inflammation in the other mucosal layers or in the sub-mucosa. This is recognized by the presence of lymphocytes and plasma cells, however, the most important factor in determining the malignant tendency of a growth is the presence of cell atypism. In the most serious type of hyperkeratosis there is proliferation of the prickle-cell layer, and also the basal layer of cells, but the basal layer in the true keratotic lesion will remain unbroken. The epithelium may send projections into the subepithelial tissue, but the cells of the basal layer remain intact.

It is felt that those showing evidence of chronic inflammation and those showing involvement of the deeper layers of epithelium are more likely to metamorphose into malignant growths. At any rate the presence of atypical cells in the epithelium signifies beginning carcinomatous changes, and if these are pronounced enough the diagnosis is "carcinoma *in-situ*." When the microscopic picture shows infiltration into the subepithelium tissue, that is, the basal layer of cells are broken through by groups of carcinomatous cells, we have a true invasive carcinoma.

Since the appearance of a lesion cannot always help us in determining the presence of malignancy we must depend upon the biopsy, but frequently a biopsy may be taken from an area that does not yet show the malignant changes. The entire lesion, if it is a large one, cannot be examined microscopically, and the malignant changes may take place over a long period and at the time of the biopsy, none of these changes as yet have occurred.

We must, therefore, approach the problem with constant awareness of the danger of complacency and treat a keratotic lesion with atypical cells as though it were malignant, and yet we must not be too radical in all cases of hyperkeratosis. We come to the conclusion, then, that cases must be considered individually, according to the site of involvement, the extent,

THE MANAGEMENT OF HYPERKERATOSIS OF THE LARYNX *†

ARTHUR J CRACOVANER, M D ,

New York, N Y

The management of hyperkeratosis of the larynx is fraught with difficulty because some of these lesions are considered precancerous, and the problems involved may defy even the most experienced laryngologist

We know that hyperkeratotic areas in the larynx may slowly and without changes apparent to the eye, develop definite malignant characteristics Since these changes frequently are not recognizable by visual examination, we must depend upon the microscopic diagnosis, second, we must consider the hyperkeratotic lesion as a malignant one, always aware of the fact that at any time the metamorphosis into cancer may take place

Hyperkeratosis of the larynx appears as a thickening of the layers of the epithelium, especially the cornified portion When it is seen as slightly raised, rather dense and thickened, white superficial plaques with evidence of inflammation, it is sometimes called leukoplakia Hyperkeratosis, also referred to as keratosis, may be localized or diffuse in the larynx It may occur on one cord as a grayish white, sessile growth or it may be seen occasionally as a red thickening on the cord It may appear as a white, warty growth with sharp, spiny protuberances It may involve all or a portion of both vocal cords, or spread to the ventricle and/or subglottic areas A typical diffuse type of hyperkeratosis is known as pachydermia of the larynx This is an involvement of the interarytenoid area that extends onto both vocal cords, usually up to the

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†From the Department of Bronchology and Laryngeal Surgery New York Eye and Ear Infirmary and Otolaryngological Service Lenox Hill Hospital

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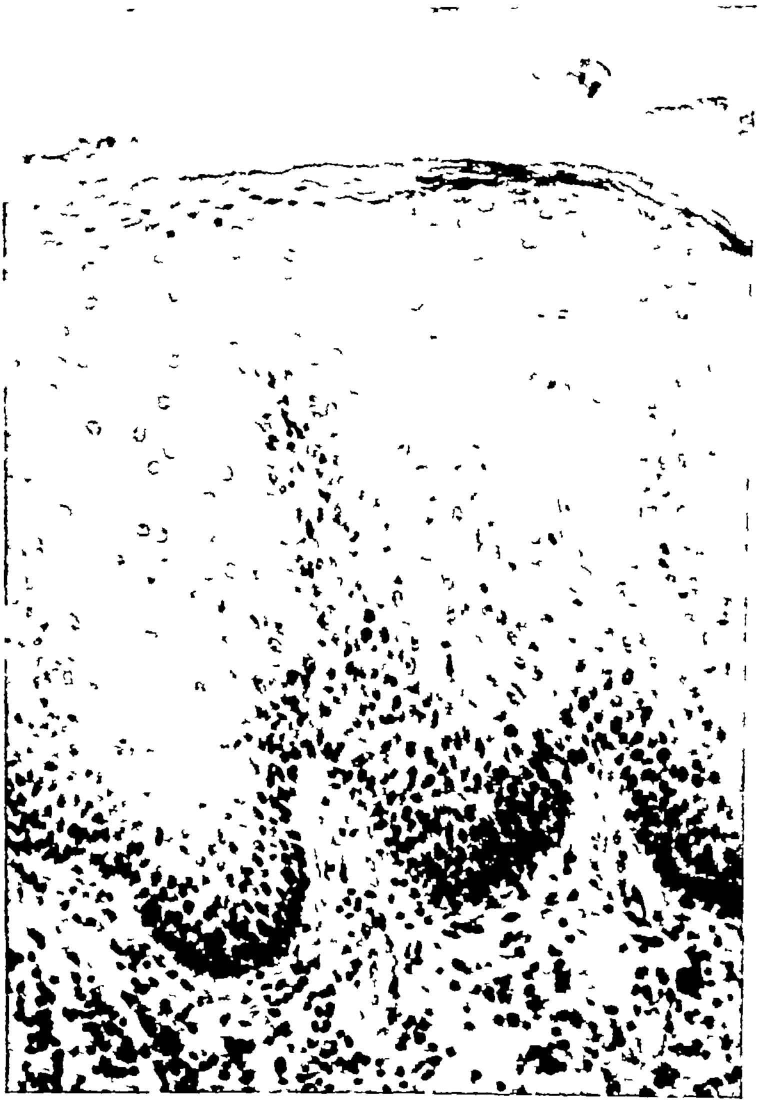

Fig 2 Leukoplakia Thickening of the corium not marked thickening of the deeper epithelial layers more marked than on Fig 1 adjacent connective tissue contains lymphocytes some cell atypism (dark staining in basal layer)

size and appearance of the lesion as well as the microscopic findings It is hard to formulate hard and fast rules, but we hope to indicate what we feel is best in certain typical cases

On examination of an early hyperkeratotic lesion, one would see a small white, elevated, thickened patch on a vocal cord, perhaps several plaques on both vocal cords They are usually seen on the upper surface of the cord, perhaps on its edge

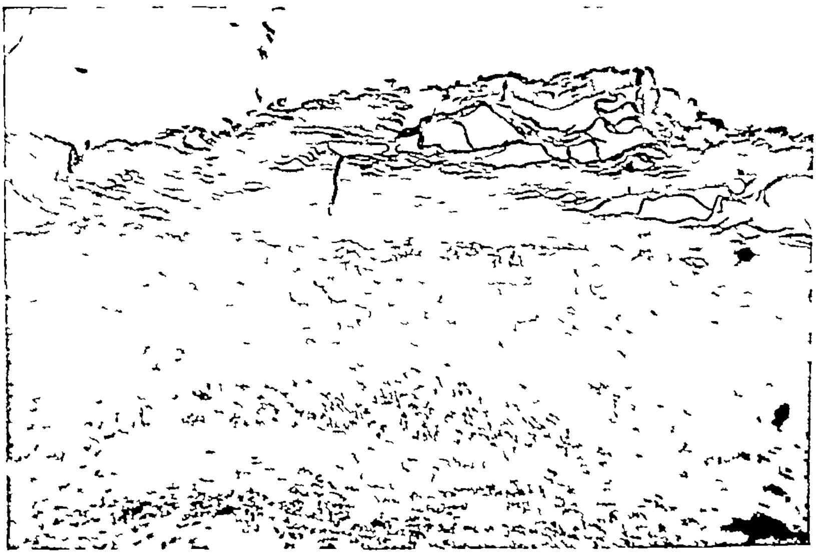

Fig 1 Hyperkeratosis Marked thickening of the corium moderate thickening of the deeper epithelial layers no significant cell atypism no inflammatory reaction in the underlying connective tissue

It is felt that hyperkeratotic lesions in general are due to chronic irritation Such irritation may be caused by excessive smoking, by excessive use of alcohol, by abuse of the voice, by inhalation of fumes and dust, they may also be caused by repeated upper respiratory infections brought on by chronic infection in the sinuses and pharynx (see Case 3) If these etiological factors can be eliminated then the hyperkeratotic areas may subside or at least not increase in size, so that this is the first advice that is given, and the patient is kept under close observation If this type of lesion does not disappear it is removed by direct laryngoscopy

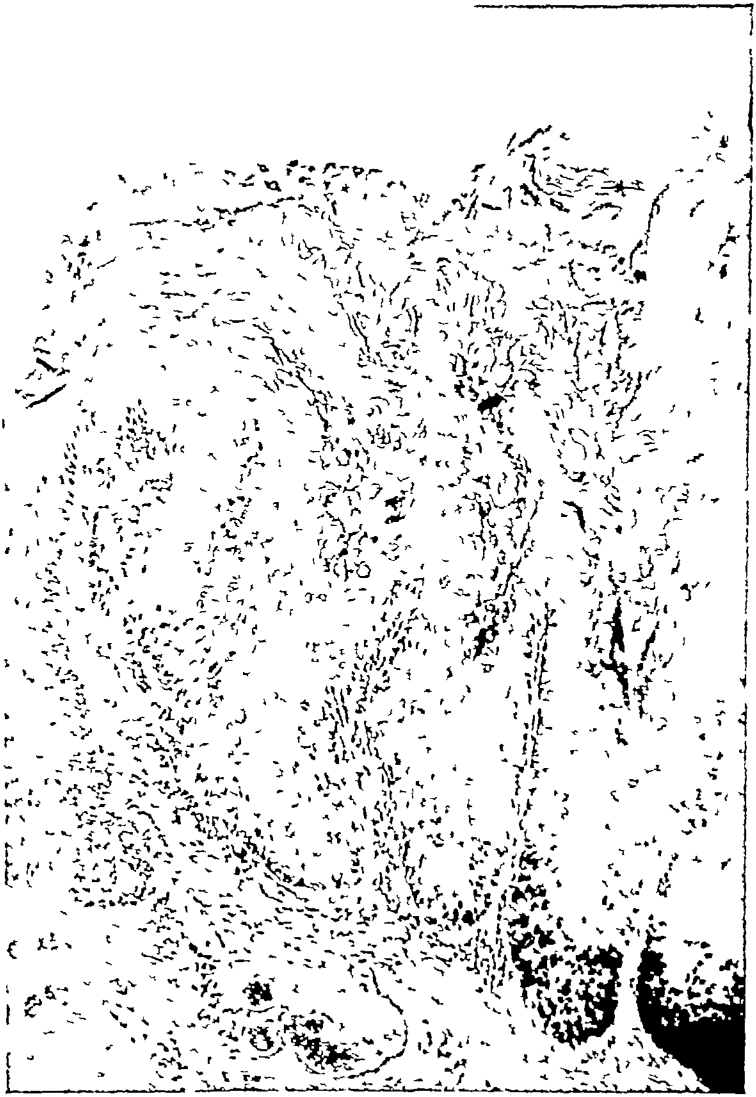

Fig 3 Carcinoma in situ As in Fig 2 but the basal layer of cells are quite atypical and show the characteristics of carcinoma i e. large nuclei atypical chromatin arrangement large nuceoli hyperchromatism large atypical shaped differentiation of squamous cells

The keratosis may appear as localized unilateral or bilateral thickenings The lesion may present itself as a grayish-white area on the cord that shows evidence of chronic inflammation The hyperkeratosis may take the form of white, warty, brittle appearing excrescences on one or on both cords Other keratotic lesions appear as whitish or red papillary growths It is felt that the presence of inflammation in or around the lesion or the warty, papillomatous growths are more likely to become malignant and yet the sessile, red thickening of the vocal cord may on occasion be reported as "carcinoma *in-situ*" Some of the above mentioned growths may subside under the regimen of elimination of the causative factors already indicated (see Case 2), but usually it becomes necessary to remove the keratotic lesion by biting off the involved areas or stripping the cords under direct laryngoscopy (see Case 1) Careful and frequent observation is most important, since at any time the lesions may recur (see Case 4) If they do, more radical therapy is indicated, since we know we are dealing with a growth that may become malignant

Perhaps we would attempt several removals of the growth by direct laryngoscopy, but we will note that with each recurrence the interval is shorter, the growth seems to grow faster (see Case 8) It is best, then, to remove the lesion by doing a laryngofissure operation For those accustomed to the technique, there may be cases with lesions small enough to be removed by suspension laryngoscopy, as suggested by Dr LeJeune Perhaps in the case of the lesion on an inflamed cord and the warty, papillomatous lesion we would be more inclined to do a larynofissure without attempts at stripping the cord Clinical experience and judgment on the part of the laryngologist will dictate the procedure to be followed (see Cases 5, 7) Of course, if at any time the microscopic findings indicate the presence or the suspicion of malignancy the growth is treated as one usually treats a carcinoma There are some hyperkeratotic lesions that spread either to the subglottic area or to the ventricle These should also be removed by laryngofissure (see Case 6)

So far it does not seem complicated, but when we have a keratotic lesion recurring on both vocal cords, perhaps ex-

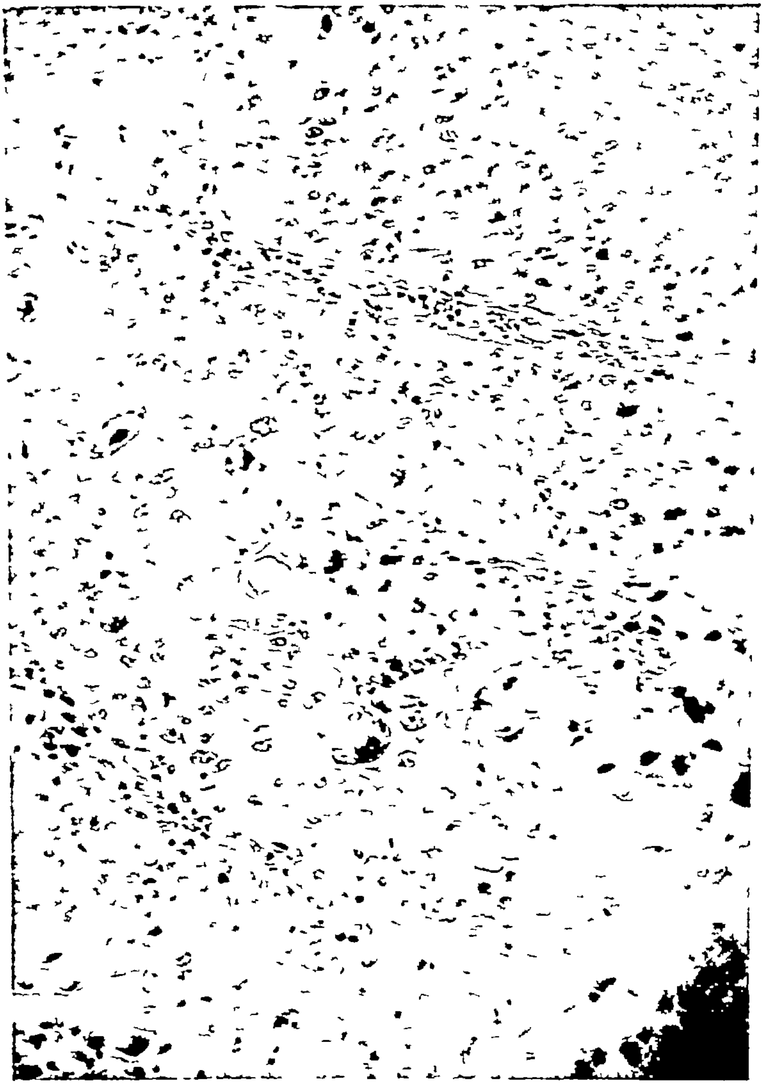

Fig 4 Squamous cell carcinoma, showing the characteristics of carcinoma mentioned in Fig 3

tending to the ventricle or the subglottic area, the situation is more serious We hesitate to do a laryngectomy in such a case when there is no definite microscopic evidence of malignancy Even if some metamorphosis that indicates beginning malignant changes is taking place, we will hesitate to do a laryngectomy, since the lesion is superficial, not infiltrating, and both cords move normally These cases sometimes do well under radiation therapy (see Cases 10, 12) Some recommend a partial tumor dose, others give a full tumor dose, according to the pathological picture and the progress during the therapy Some laryngologists state that the vocal cords return to their normal appearance, but that has not been my experience The cords seem to be thickened and white, and one must keep these patients under close observation for recurrence of a hyperkeratotic lesion It is felt that partial doses are less likely to cause mucosal changes within the larynx, and the cords approach the more normal appearance One wonders whether we should chance the partial dose Under radiation therapy one can never be sure of a cure, certainly not so sure as when a lesion is removed surgically We repeat then, a case of hyperkeratosis that would require a laryngectomy for complete removal is first treated by X-ray

Occasionally one encounters a case where an entire cord is involved, and the growth extends across the anterior commissure for a short distance on the other cord (see Case 7) This can be treated by doing a bilateral thyrotomy, as suggested by Kemler, or the partial anterior laryngectomy as suggested by Jackson

The cases that are puzzling are those known as pachydermia of the larynx, where the interarytenoid area and part of both vocal cords are involved To eradicate this disease surgically, one would require laryngectomy These patients are best treated by stripping the involved areas, by eliminating the irritating causes, and by close observation If any malignant changes do occur a laryngectomy becomes necessary

There is an occasional case where the tumor becomes very extensive, and, even though on repeated biopsy they are reported hyperkeratotic lesions, they should be treated by

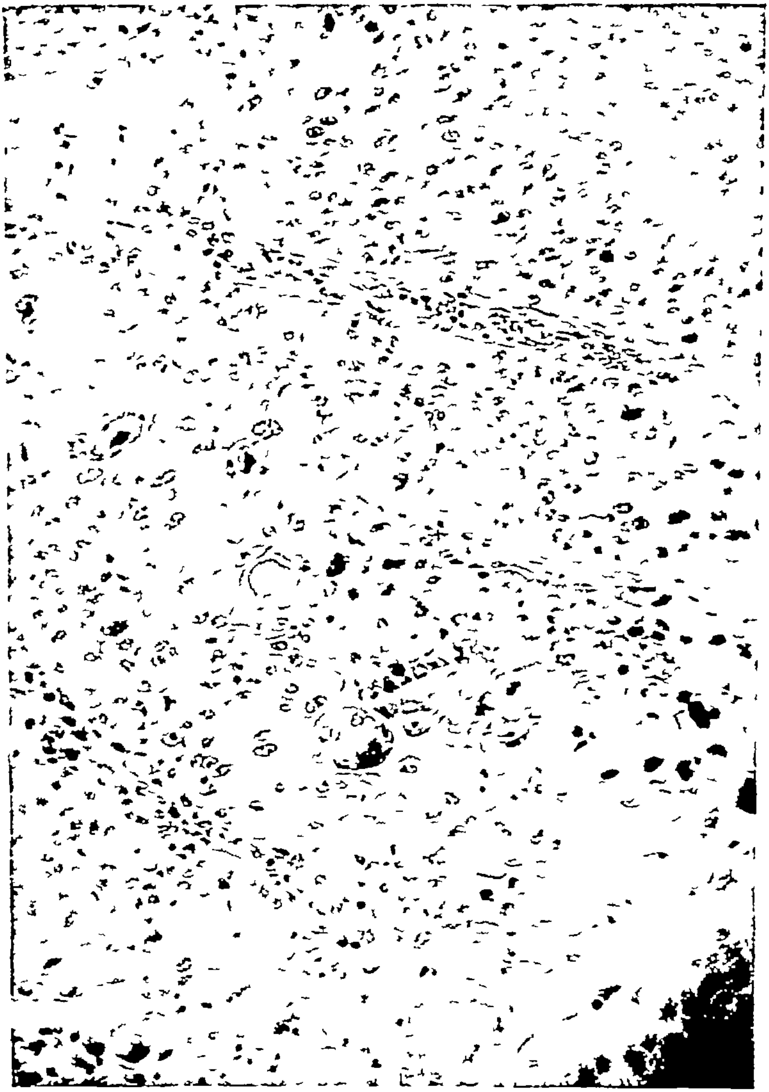

Fig 4 Squamous cell carcinoma showing the characteristics of carcinoma mentioned in Fig 3

laryngectomy (see Cases 9, 11). Recently we had the experience of procrastinating on just such a case because we found no evidence of malignancy microscopically, but clinically it was a carcinoma. It spread down the trachea, involving the tracheal stoma, infiltrated the tissue in the neck, and resulted fatally.

CASE REPORTS

Case 1. M. A.—White, male, age 70. Hoarseness for many years. There was a red thickening on the anterior two thirds of the left vocal cord. This area was stripped under direct laryngoscopy. The microscopic diagnosis was keratosis with some atypical cells, no evidence of malignancy. This patient has been under observation for three years, with no recurrence.

Case 2. E. M.—White, male, age 12. History of hoarseness for three months. There was a small irregular tumor in the anterior third of the left vocal cord. This was removed under direct laryngoscopy. The diagnosis was hyperkeratosis of the vocal cord with no evidence of malignancy. The patient was advised to undergo a regimen to eliminate irritation of the larynx. He has remained free from recurrence for over a year.

Case 3. S. H.—Age 59, W. F. The patient had a history of recurring attacks of laryngitis. The last attack had been present for four months. On examination she had a red, dry, granular appearing vocal cord. The diagnosis was laryngitis sicca. The patient had a chronic sinusitis, postnasal pus and atrophic appearing mucosa of the pharynx. On direct laryngoscopy there was thickened, irregular mucosa involving the arytenoid area and the vocal cords. The microscopic diagnosis of the tissue obtained was hyperkeratosis, no evidence of malignancy. The patient improved on treatment of the chronic sinusitis. It is important to point out that in this case there were no atypical cells and, therefore, it would not be considered a precancerous lesion.

Case 4. I. T.—Age 60, W. M. In May, 1955, he gave a history of hoarseness for three weeks. He had a lesion involving the left vocal cord, it appeared white and irregular. On direct laryngoscopy the cord was stripped. The microscopic diagnosis was keratosis with cell atypism of the left vocal cord. No evidence of malignancy. In May, 1956 the patient again complained of hoarseness for two months. There was a whitish superficial lesion on the right vocal cord extending from the anterior commissure to the middle third of the cord. This area was stripped under direct laryngoscopy. The microscopic diagnosis was hyperkeratosis of the right vocal cord with slight atypism but no changes indicative of carcinoma at present. In June 1956, there was a recurrence of the lesion that involved the middle third of the right vocal cord, the diagnosis was hyperkeratosis with granulation formation. This patient has been under observation and there has been no evidence of recurrence to date.

Case 5. A. S.—Age 69, W. M. This patient gave a history of hoarseness for three months. He had a large keratotic appearing lesion on the right vocal cord and subglottic area. Several specimens for biopsy revealed hyperkeratosis with suspicious areas of cellular activity and considerable inflammation. Because this was a warty, irregular appearing lesion that involved the subglottic area a laryngofissure was performed with removal of the entire growth. The pathological diagnosis of the laryngofissure specimen was carcinoma *in situ* in a hyperkeratotic lesion

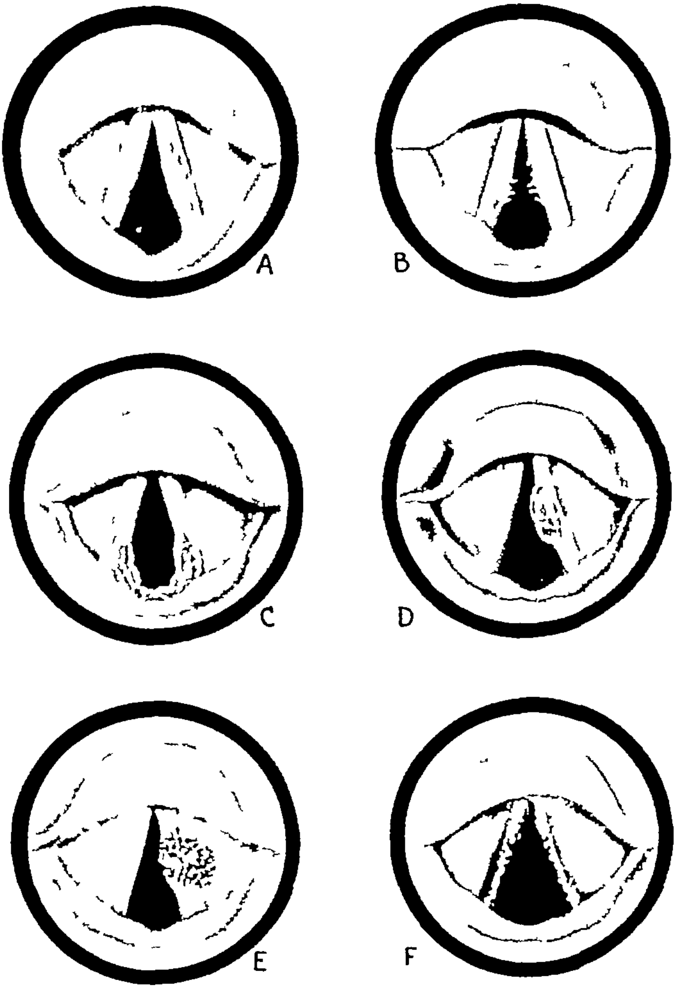

Fig 5 A.—Leukoplakia B—Keratosis C—Pachydermia D—Hyperkeratosis with carcinoma in situ E—Hyperkeratosis with carcinoma in situ F—Bilateral Hyperkeratosis

This patient unfortunately died of carcinoma of the right upper lobe with metastases a year later

Case 6 M C—Age 57 W M This patient had five endolaryngeal removals of polypi and keratotic lesions Two years prior to admission he had had a tracheotomy at another hospital At this admission he was having respiratory difficulty He had a large grayish white cauliflower lesion in the glottic lumen apparently arising from the anterior third of the left vocal cord After the preliminary tracheotomy a laryngofissure was performed and a sharply circumscribed, elevated whitish lesion was removed from the inferior surface of the left vocal cord and subglottic area The pathological diagnosis was hyperkeratosis of the larynx with no anaplastic changes noted The patient has remained well to date four years This is an example of persistent recurrence of a laryngeal hyperkeratosis and the growth of the lesion to such an extent that *it gives laryngeal obstruction It is significant too that no evidence* of carcinoma was found, even after the laryngofissure

Case 7 P P—Age 60, W M In April, 1955, complained of hoarseness for several months He was a heavy smoker and drinker On examination a whitish lesion was found covering the anterior two thirds of the left vocal cord, reaching the anterior commissure After a direct laryngoscopy, the biopsy revealed a keratotic lesion of the left vocal cord with some cell atypism malignant transformation not evident Because of the appearance of this lesion a laryngofissure was done The left vocal cord was removed and since the lesion extended across the anterior commissure on to the right vocal cord a small portion of the latter was removed The diagnosis was left vocal cord leukoplakia with carcinoma *in situ*, the right vocal cord showed leukoplakia of slight to moderate extent The patient has remained well, though he has a small web in the anterior commissure This case illustrates the fact that if the lesion is large and irregular and when the microscopic section shows some atypism, it is best to do a laryngofissure immediately A carcinoma *in situ* was found on complete removal of the growth

Case 8 H S—Age 49 W M This patient complained of hoarseness for six months There was a lesion on the middle third of the left vocal cord It was granulomatous grayish white in appearance It was removed by direct laryngoscopy The microscopic diagnosis was hyperkeratosis of the vocal cord There was evidence of inflammation in the underlying tissue Three weeks later there was a recurrence of the lesion in the left mid subglottic area This was removed and on microscopic examination revealed a carcinoma *in situ* Two weeks later a laryngofissure was performed and the diagnosis was epidermoid carcinoma very early, showing slight infiltration of the underlying tissue This is a case of hyperkeratosis in which the metamorphosis into a carcinoma occurred rapidly or perhaps as is more likely the tissue was taken from the areas where the carcinoma did not appear

Case 9 M D—Age 55, W M This patient appeared June, 1956, with a complaint of pain on the right side of his neck There was an enlarged node over the carotid on the right side On laryngeal examination there was a superficial grayish ulceration on the posterior surface of the right side of the epiglottis and right aryepiglottic fold extending down to the anterior commissure The left vocal cord was a little roughened biopsy was taken Diagnosis was hyperkeratosis with a few atypical cells no evidence of malignancy Since a carcinoma was not definitely found in the larynx we decided to remove the enlarged lympho node This was reported as chronic lymphadenitis In Sept 1956 the lesion looked about the same except that it seemed to extend on to the right vocal cord Another biopsy at this time revealed carcinoma *in situ* developing in hyperkeratosis of the larynx A laryngectomy was performed and the diagnosis was squamous cell carcinoma of the larynx microscopic examination of the vocal cord itself showed hyperkeratosis This patient has remained well for over a year The case illustrates again that the biopsy may be taken from an area that does not reveal carcinoma When one is suspicious of carcinoma the biopsy should be repeated

Case 10 E G—Age 49 W F This patient complained of hoarseness for two years Both vocal cords were thickened and dry, the right ap peared more involved than the left The interarytenoid area was also thickened and irregular The tissue removed from the larynx revealed a hyperkeratosis of the vocal cord and interarytenoid area with slight atypism This patient was referred for radiation therapy She has remained well for two years

Case 11 J G—Age 75 W M In December 1954 this patient had ulcerated appearing vocal cords but no fixation of the cords The cords were thickened white and had an irregular, warty appearance The diagnosis on biopsy was leukoplakia with considerable cell atypism not yet definite carcinoma Two months later the lesion looked worse and the biopsy revealed squamous cell carcinoma A laryngectomy was performed and the patient has remained well to date It is possible that a case of this sort should have been treated by radiation therapy but it was felt that this warty extensive lesion should be removed surgically

Case 12 H S—Age 63 W M Jan 1956 this patient had had hoarseness on and off for 15 years The recent attack of hoarseness had lasted four months He had a reddish thickening on the left vocal cord and a white plaque on the right vocal cord A biopsy of the left vocal cord was reported as malignancy of a low grade The right vocal cord was reported as leukoplakia He was sent for radiation therapy and has remained well however, he does have thickening of both vocal cords

CONCLUSIONS

1 Those hyperkeratoses that show cell atypism are serious because they are precancerous Since it is sometimes difficult to tell when the lesion will become cancerous it should be treated as a potential malignancy

2 The early lesions are treated by stripping the cords under direct laryngoscopy and eliminating irritation due to tobacco, alcohol, abuse of the voice, infection, etc

3 Recurrent lesions on one vocal cord or large warty lesions on one cord that involve the ventricle and/or subglottic area are treated by laryngofissure

4 Recurrent lesions on both vocal cords are treated by radiation therapy, and if unsuccessful by laryngectomy

5 Extensive laryngeal involvement should be treated by laryngectomy

I am indebted to Dr George K Higgins for his help in the pathological aspect of this paper

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SYMPOSIUM

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HAROLD OWENS, M.D., Los Angeles, Calif.
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DISCUSSION

I. B. GOLDMAN, M.D., New York, N. Y.
A. W. PROETZ, M.D., St. Louis, Mo.

PROBLEMS THAT CONFRONT THE RHINOLOGIST*†

JOSEPH H. OGURA, M.D.,
St. Louis, Mo.

INTRODUCTION

To many otolaryngologists, the subject of reconstructive nasal surgery sounds broad and includes all phases of rhinoplasty. Actually rhinologists who perform this operation use this term in a more limited sense. Total nasal reconstruction, such as the use of forehead flaps for the replacement of partial or total loss of the external use, is in the realm of the plastic surgeon. One may justly wonder then, how this fits into our field of rhinology? The otolaryngologist, by training and everyday practice, has always concerned himself with the

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†Department of Otolaryngology, Washington University School of Medicine, St. Louis, Missouri.

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function and health of the nose A few, by greater experience, have become more involved with plastic surgery in its strictest sense Thus, a casual observer may consider a rhinoplasty as a purely cosmetic procedure, and naturally wonders about the functional improvement claimed by such an operation

I shall try to cover briefly four questions in a general way

1 What do you do?

2 Why do you do it?

3 Do you accomplish what you claim physiologically?

4 How important is this?

It is not my intent to compare different schools of thought or to answer these four questions specifically, but to give a fundamental philosophical concept of handling a nasal problem

It would be an easy matter to discuss this subject if the functional considerations for this surgery were clearcut We owe a great deal of the present knowledge on the physiology of the nose, the nasal mucosa, turbinates and sinuses to the pioneer work of Jonathan Wright, Zwaademaker, Gray, Yates, Hartz, Proetz, Hilding and many others Dr Proetz has said that the normal nose is one that is symptom free, smoothly breathing with slit-like passages[1] It is to him that we owe the understanding of how air currents pass through the nose

On the other hand, such functional alterations as deviation of air currents and direction of flow ascribed to minor anatomical variations of the external nasal pyramid and lobule from the "normal" are not so well known Some ideas have been expressed that traumatic injury which causes flattening of the lobule, and broadening of the base will convert elongated to round nostrils and may then alter air currents and cause symptoms

It has been further expressed that the surgical correction of the lobule, or a deviated pyramid, back to "normal" offers a more normal and harmonious relationship of the various anatomical parts with the objective of breathing better Good anatomical restoration can be quickly determined by comparing a preoperative photograph with the operative result, but one cannot always demonstrate a functional improvement The term function has been used all too loosely, and it may be invoked as a necessary prerequisite for a nasal operation

No one will deny that when the septum obstructs one nostril, or is deviated so as to cause persistent impairment of the airway, surgical correction will give a satisfactory improvement in that patient It does not necessarily follow, however, as far as very external nasal structure is concerned, that important physiological significance need be attached for every architectural aberration from "normal" An expression of an opinion is one thing, but facts documented on objective findings are another

Our problem then, is just what is the normal nose? Are anatomical variations from "normal" abnormal for that patient? The restoration of an obstructed nose to "normal," to some may be more in terms of function, to others an emphasis on cosmetic appearance The latter may be art, but it certainly is not science The rhinologist is concerned with *breathing* or the symptomatic counterpart *nasal obstruction* The restoration of such an airway is his interpretation of what an *adequate* airway should be Since the nose cannot be compared to the highly developed sensory organ, such as the ear or eye, in that we cannot objectively measure what is taking place with respiration, we have no unit of measurement similar to the audiometer and speech test in audiology One interprets the patient's complaint of nasal obstruction on the anatomical findings and can attempt to evaluate it only physiologically This is our one criterion for surgery

Since the impressive work of Proetz,[1] we have not advanced significantly in the field of physiology of the nose to the point where one can relate function with anatomic changes of the entire nose We have made remarkable advances in techniques of *rhinologic surgery in terms of preservation of* turbinates, and nasal mucosa and avoiding radical sinus surgery, but as yet we have no way of measuring nasal function in relation to the lower respiratory tract There are rough methods for measuring airway by breathing upon a cool, polished metal surface, or more refined methods using the nasometer or rhinometer We have taken measurements in various rhinologic diseases where nasal obstruction is present by using the rhinomanometer [2,3] While the latter observations are important, this does not tell us too much about the physiology of breathing or respiration from the nose to the lung Simultaneous observations on the nose and lung from a functional point of view that are being made under controlled laboratory situation, show that there may be some important relationship [4] Why is it that a person with chronic lung disease complains of nasal obstruction, and his symptom of dyspnea is relieved if he can breathe better through the nose? Why does the occasional patient with a badly obstructed nose complain of dyspnea? Such problems are now under investigation

The lack of objectivity in evaluating results (other than cosmetic improvement), the marked variation in complaints in patients with the same anatomic deformities (the psychosomatic and psychiatric aspects), the poor standardization of language among rhinologist and plastic surgeons, and the lack of a unit of measurement which is meaningful in terms of function, make it difficult to communicate with members of the profession, let alone our own colleagues in the field of rhinology This does not mean that we are not trying to explore means of solving these perplexing questions Measurement of architectural changes with growth and by trauma using nasal indices, cephalometric laminography are being investigated at the present time One could assume the view of simplifying function in terms of our knowledge today, that the nose is an airway, air conditioner, filter, humidifier and an olfactory organ

Our problems are quite similar to the field of orthodontia, and we are in a position of trying to establish this phase of rhinology as a science Orthodontia has developed greatly, and after years of precise observations, evidence has accumulated that alterations to the teeth in the child in no way predictably changes the growth of the maxilla or the mandible The restoration of teeth to their proper anatomical relationship cannot, to this day, be related to their function [5]

With such limitations from the accepted functional point of view, it is obvious that the criteria for restoration of the nose to their proper anatomic relationship will have to be explained on other factors The feeling seems to be prevalent that in a patient with a deviated septum or in another instance with a hump, physiologic needs are involved in order to justify the performance of a rhinoplasty While in some instances this is necessary, in many other instances this will not be true

The history of septal surgery reveals that the submucous resection, as advocated by Freer and Killian, was a satisfactory procedure when performed in certain types of deviated and obstructed septum It was the functional and cosmetic complications, perforations, immediate and late saddling, and the retracted columella that was feared Some of us knowingly, up to the 1940's, avoided operating upon a badly twisted septum, particularly when associated with a severely deformed external nasal pyramid with a tendency to sag on the dorsum, for fear of making this worse If we had more courage we still did an incomplete septum operation, and we had difficulty in obtaining a satisfactory airway If the patient asked for a repair of the hump, our deficiencies in handling this problem meant two separate operations, or calling in a plastic surgeon to handle the external nasal problem at the same time

In the deviated nose, it is recognized that one cannot adequately straighten the septum without operating on the external nasal pyramid Versatility of surgical approach for handling such problems is dependent upon the presenting anatomic problem

When the patient complains of unilateral persistent nasal obstruction and the septum obstructs this airway, this can be easily understood, on the other hand, there are just as many patients who have a badly traumatized nose with septal obstruction without any complaints Some atrophy of the interior of the nose may be present, and in this instance surgical correction may be indicated, even without complaints One explains the absence of complaints on the basis of the marked "compensatory process" of the nose Combined septal and external pyramid surgery in another patient with the identical deformity, but with the chief complaint of nasal obstruction may be warranted This patient may have subconsciously wanted his hump removed When one obtains a satisfactory esthetic and cosmetic result, the patient at the conclusion of the post-operative period may only comment, "I can now breathe better" To this day, this is about the only criterion we have for improving this patient from the physiologic point of view Of course, the patient will also be satisfied with his appearance, but one well knows how unreliable it is to depend upon what the patient says about his improvement of breathing and disappearance of many other secondary complaints Infrequently nasal obstruction is still present, in spite of what appears to be an adequate airway and satisfactory cosmetic operation

In some instances we can relate nasal obstruction to deformed upper lateral cartilages ("ballooned or collapse of the upper lateral cartilages"), and surgical techniques have been devised for preserving and correcting the so-called "valve" area Alae collapse in moderate forced inspiration has been seen, and pressure measurements in such instances have been made[3] Here surgical correction will require a total nose operation Total nasal procedures are necessary to correct septal perforation, utilizing the principle of preserving nasal mucosa and rotating tube flaps from under the upper lateral cartilages and from the floor of the nose

The problem of nasal obstruction in many cases is similar to that of the deaf patient Some deaf patients get along very well and do not want or need surgery Likewise, many patients with obviously obstructed septums do not complain of nasal obstruction, nor do they desire surgery

The indications for surgery on the total nose, where the septum is obstructive may be done for one of two reasons

1 To restore a proper airway which may entail cosmetic change Some cosmetic changes may not be requested by the patient Some patients desire this change subconsciously or only if brought to their attention In others cosmetic changes may become evident during or after surgery

2 For cosmetic purposes

It is assumed that the surgeon has taken precautions for not operating upon patients with psychiatric problems It is particularly hazardous to operate upon patients who use their noses as a "crutch"

Certain deformities of the nose, associated with the complaint of nasal obstruction, require surgery upon the septum as well as the external nasal pyramid The prize fighter's nose is a good example In another instance, a twisted external nasal pyramid will prevent a deformed septum from being brought into its proper relationship unless the pyramid is restored to the midline There are other examples The patient may desire only a cosmetic change, and surgery to the septum is necessary if one is to restore the nose to the midline It is recognized that the septum is the main supporting structure of the nose, and procedures which interfere with the septum the least, by gridding, cross-hatching, moving the maxillary crest to the midline, maintaining attachment of mucoperichondrium to one side and suturing the cartilage to the periosteum, it is believed that subtotal removal of the cartilage yields the best results for the septum and cosmetic appearance The more extensive the septum surgery the more difficult it becomes to achieve the desired cosmetic result This is particularly true when the caudal end is removed Immediate saddling may result, but this can be avoided or minimized by subtotal removal

Evaluation of the result is difficult when one is confronted with another type of problem A satisfactory cosmetic result is obtained with an obvious narrowing of the nasal airway The patient is quite happy with the appearance of his nose and he has no complaints of his airway This is sometimes the case when the patient's only presenting complaint is "to have the hump removed"

From the cosmetic point of view it becomes quite apparent, as one performs more of these operations, that one cannot become critical of the cosmetic or functional result obtained by other surgeons Beautiful or mediocre results depend upon the initial problem, furthermore, what looks like a satisfactory result may change with time Following surgery minor trauma may create further architectural deformity to the nose, such as a slight sag of the dorsum and a retraction of the columella What is most important in any given case is that the operator can predict prior to and during the operation what may happen, anticipate such complications and institute appropriate corrective measures

The decision has to be made as to whether to divide the operation into two procedures or whether it may be preferable to combine the operation as a one-stage procedure When one interprets in terms as to what is best for the patient, it is always better to do the operation in one stage if possible I cannot say that the plastic surgeon is concerned with cosmesis alone, and is not interested in the airway in all instances

The position in which the otolaryngologist finds himself is obvious A properly trained rhinologist should be the logical one to cope with a problem of this sort, which is complicated by consideration of improvement in function, cosmetic appearance and social well-being of the patient

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HOW DO YOU GO ABOUT MAKING A DIAGNOSIS IN SOME OF THE MORE IMPORTANT RHINOLOGIC DEFORMITIES?[*][†]

HAROLD OWENS, M D ,

Los Angeles, Calif

If any one thing comes to mind it would be to say that making a diagnosis encompasses the whole totality of the nose, both inside and out One cannot merely say that the patient has a hump or a saddle, or the nose deviates We must know all the parts of the nose which produce the deformity and their relation to each other

To arrive at a diagnosis, some arbitrary classification is necessary in order that the surgeon can decide what to do With very few exceptions, one should have the diagnosis pretty well made and the operation mentally done before entering the operating room, however, the diagnosis may not be complete until the patient is anesthetized, or until part of the surgery has uncovered the deformity

A working classification for diagnosis should encompass the following

We are interested in the texture of the skin, whether it be thick and oily, thin and atrophic, or of relatively normal appearance

Thick, oily skin often interferes with proper narrowing of the nose, particularly in the lobular area An extreme example of this is a patient I operated recently who had had both lateral crura removed at a previous surgery and yet the tip was still quite thick, and there was no collapse of the nares Thin, atrophic skin offers problems of contractural deformities after surgery

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[*] Read as part of a Symposium at the Sixty-First Annual Meeting of the American Laryngological Rhinological and Otological Society Inc San Francisco Calif May 21 1958

[†] From the Department of Otolaryngology University of Southern California

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Septal obstruction with minimal or no external nasal deformity

Obviously this is a personal matter with the physician A Killian or Freer septal procedure is quite adequate, and no external nasal pyramid surgery is needed

Septal obstruction with a dislocation of the caudal end of the septum off the nasal spine and premaxilla into the vestibule with minimal external deformity

This type of deformity will need a subtotal, or total removal of the septum, including a complete mobilization of the caudal end of the septum in the maxillary spine area External pyramid surgery may or may not be indicated

The deviated or twisted nose, usually of traumatic origin

Such a nose has been discussed fully by Huffman and Lierle * This type of nose runs the gamut of diagnostic problems One should note the deformity of the dorsum, or more correctly the sagittal alignment Is it "C" shaped, "S" shaped, or merely deviated Sagittal alignment with other structures of the face and teeth must be considered Other accompanying deformities of the maxilla and teeth might propose the question whether a nose should be replaced in the midline

The nasal bones are usually uneven and asymmetrical, and there may be a hump These conditions are of prime importance in determining hump removal and the level of lateral osteotomies

The relationship of the upper lateral cartilages to the nasal bones, as well as the septum must be determined Often the deviation may involve only the cartilaginous vault and septum, and correction of this area is all that is necessary The upper lateral cartilages may be torn from their attachment to the nasal bones, and present inequalities

The lobule-septal relationship should be noted Is the twisted tip and columella due to septal dislocation or it is due to lobular deformities, particularly the medial crura?

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*Huffman W C and Lierle Dean M. The Deviated Nose Ann Otol Rhinol and Laryngol Vol 63 Mar 1954

The deviated nose offers the most difficult problems in diagnosis and management, as it requires the mobilization of the septum and external nasal pyramid as complimentary procedures, and in most cases the procedures should be done at the same time This type of nose should be the great concern of the rhinologist

A high narrow nose with an excessively long septum

This type of nose often appears like the tip is hanging on the end of the septum and is most pronounced when the patient smiles or purses the lips One should note the lobular cartilage development, as the lack of projection of the tip may be more apparent than real, and all that is necessary is to decrease the projection of the bony and cartilaginous dorsum, this must include the dorsum of the septum also The nose actually must be widened

We sometimes see a low flat nose with a deviated caudal end of the septum

This type of nose usually results from poor tip development as a result of childhood injury, and most of the pathology will be in the cartilaginous pyramid and septum One should decide whether the cartilaginous saddling is due to loss of septum, atrophy of the upper lateral cartilages, or both

The caudal septum may lie almost at right angles in the nose, or be quite short The latter is often accompanied by a poor maxillary spine and retraction of the naso-labial angle These areas must be carefully studied, as the correction of this deformity usually requires the use of implants of various types

The straight humped nose with or without a drooped tip offers little problem

This is the so-called "cosmetic type" and can be and is handled by a typical Joseph rhinoplasty The only problem is that the septum should be studied, as many of these patients have a good cosmetic result, but they will often tell you they cannot breathe well after the surgery

In any work of this type the psychological diagnosis is important

A large percentage of patients come to us merely because they want cosmetic improvement, although this may not be the presenting complaint Many of these patients have used their nasal problem as a crutch, and we must be careful not to remove this crutch and in so doing possibly convert a psychoneurotic into a psychotic personality

These are just a few of the problems to consider in arriving at a diagnosis of basic nasal deformities

SURGICAL MANAGEMENT PHASE*

RUSSELL I WILLIAMS, M D ,

Cheyenne, Wyo

It is my deep conviction that it is in the best interest of all that one school of thought not be pitted against another It is rather my belief that a discussion will bring to all of us a better understanding of the many facets of this perplexing problem In turn, this will stimulate study and advancement in our field of rhinology

From a broad, philosophical standpoint, our concept considers the total nose, the total relationship of all of the components of the nasal septum, the external nasal pyramid and the internal nose, therefore, the surgical procedure for restoration of proper anatomical relationships must, of necessity, not be limited to only one portion of the nose

We all agree, I believe, that the nasal septum is the main supporting structure of the external nasal pyramid Modifications of the nasal septum create problems in direct proportion to the extent of disturbance of septal totality With extensive disturbance, complications such as saddling, retraction of the columella, and widening of the nose may occur

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Many of us have observed these complications during and following surgery It is our belief that these complications should be anticipated, and methods of correction instigated during surgery and, of course, avoided if possible

The versatility of the approach by application of rhinoplastic techniques, not necessarily original, to septum surgery, the preservation of the mucosal flaps and preservation of the skeletal portions, as well as the soft structures, allows the freedom to perform surgery on the nasal septum and the adjacent external nasal pyramid and, in many instances, the internal nose, in one surgical procedure This flexibility, in my experience, allows us to modify and attempt to restore proper relationship of the component structures, and to restore totality to the best of our ability This results in a better nose from a cosmetic aspect, and allows the patient to breathe better

Now, what is a normal nose? Dr Proetz[1] defines the normal nose as follows "The normal nose, or perhaps better the symptom-free, smoothly breathing nose, is characterized by slit-like passages—slit-like everywhere and not merely above, in the olfactory area "

The normal nose is difficult to define because each individual nose has its own peculiar characteristics, structural variations, as well as functional, when we consider the total personality

We are all aware of the tremendous inherent compensatory powers of the nose We are also aware of variations which in one person may produce symptoms, in another they may not, and on clinical examination very little difference can be observed in the structures of the nose

We do feel, however, that there should be a proper relationship of the vestibule to the *os internum* of the nose, and also a proper relationship of the lateral walls of the nose to the nasal septum Here again it is difficult to put into figures just what this relationship is

Studies of the various indices, such as the choanal index and the clinical nasal index, as well as the X-ray nasal index, give us figures which are only relative, but which do help in evaluation to some extent

The attitude of the nostrils plays an important role When the nostrils are round and wide, usually the *os internum* is similar, and an excessive amount of space is usually present between the lateral nasal wall and the nasal septum We are particularly concerned with injuries to the Caucasian nose which may simulate, in many respects, a nose of a different ethnic origin A study of embryology is quite revealing in this respect, neither can anthropological considerations be ignored In reconstructive surgery, an attempt is made to restore these relationships to what we feel is normal for that particular nose

What do we mean by "breathing" and what is an "adequate airway?" My conception of an adequate airway is one in which there is not an excessive amount of space in the nose from the nares to the posterior choana, but rather one in which the passages are comparatively narrow and streamlined One is struck by the fact that the passages are slit-like, and many structural prominences are noted which seem to encroach upon the lumen Breathing is an esthetic sense, and to date we have not found a satisfactory definition

Our knowledge of the exact function of the entire nose or, for that matter, the exact function of any integral portion of the nose is limited We feel that the nose should function as a unit and complement the other structures of the respiratory apparatus To my knowledge, we do not have a satisfactory explanation clearly establishing the nose-lung or the mouth-lung relationship

It is true, that anatomical shapes and relationships may be mistaken for functional necessity, but again as Dr Proetz mentions, the structural variations may be useful as a starting point, providing that we recognize our limitations

Deformities of the external nose are frequently the result of injuries or developmental abnormalities The deformities may involve any or all parts of the external nasal pyramid and the nasal septum

To reconstruct and to restore, or provide totality to the best of our ability, it may be necessary to separate the component structures, either partially or completely, and to move and reposition, or remove and replace the component parts

The modifications of the septum may require conservative or extensive procedures In either case, it should be feasible to accomplish the result with, *1* minimal injury to the mucosa, *2* with rigidity restored to the nasal septum, *3* with sagging of the cartilaginous dorsum prevented, or corrected if it was present or occurred, and *4* with prevention or correction of post-operative or post-traumatic widening of the nose[3]

The exposure to the septum should afford us opportunity to observe adequately and to perform surgery on any portion or portions of the nasal septum

Frequently the septum operation alone is inadequate to restore proper anatomical relationships We will concern ourselves with four categories of deformity which may require attention in conjunction with the septum operation

The first category includes those which require surgery of the lobule in addition to modification of the nasal septum

The second category involves those which require surgery of the external nasal pyramid, but in which a hump removal is not needed A good example of this is the injured nose that is leaning to one side and possibly twisted

The third category comprises those patients who require rather extensive modification of the septum, removal of the hump, modification of the cartilaginous vault and the lobule The classic example is the severely twisted or deviated nose

In the fourth category, the typical boxer's nose would be the classic example This nose would require extensive septum surgery, moving of the bony external nasal pyramid, modifications of the cartilaginous vault and lobule

Preservation of the mucosal flaps and their attachments in entirety or in part, makes the combined operation possible

In addition to this, if possible, preservation of the attachments of the upper lateral cartilages and the attachments of the nasal bones to the septum, help support the nasal pyramid If at all possible, we like to leave a portion of these structures attached to the septum, however, if we have an intact mucosal tunnel, by preservation of the mucosa, the intranasal dressing will serve to hold the structures in position for adequate healing

These attachments may be severed and still preserve the mucosal flap by separating them intraseptally or extranasally The nasal bones may be separated from the bony septum in a similar manner If the septal flaps have not been elevated, it is possible to perform a rather extensive submucosal elevation of the upper lateral cartilages and the undersurfaces of the nasal bones The upper lateral cartilages and nasal bones can also be separated via this approach This procedure is also rewarding in attempting to close a septal perforation by merely continuing the elevation from the undersurface of the upper lateral cartilages and the nasal bones onto the septum, and allowing the mucosa to drop, and also raise the mucosa from the floor of the nose so as to close the hole of the perforation

There are many procedures which can be used to remove the hump Certainly the saw is very effective, the chisel is likewise effective Other methods have been advocated and they are very useful

We believe, however, that by not being bound by any procedure or routine, the flexibility of approach, the preservation of mucosal flaps and the selective use of various techniques, in part or in whole, at will, and as may be indicated in a given circumstance, enables us to gain our ultimate objective

In summary, our concept is in no way original It involves the application of rhinoplastic techniques, providing us with a versatile approach to many variable problems encountered in reconstructive surgery of the nose

Preservation of the mucosal flaps and preservation and modification of the structures provide us with a method whereby restoration of anatomical relationships can be accomplished and the totality of the nose restored to as near normal as possible

We do not know all the answers to the surgical phase Neither do we know the answers to the functional phase We are critically reviewing our results and hope that this will lead us to the solution of the many problems with which we are faced

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DISCUSSION

Irving B Goldman M D (New York, N Y) I am in accord with the basic philosophy of all the panelists and agree that total reconstruction of the nose be left to the general plastic surgeon where restoration is primary and function secondary The problem of nasal physiology I shall leave to Dr Proetz I should prefer to consider the practical aspects of rhinoplasty

Before I do so I should like to discuss the antagonistic attitude to the term "rhinoplasty' by many physicians and surgeons The various synonyms require reevaluation of what constitutes the correct term for "cosmetic" plastic surgery of the nose

Some of the names and phrases indicating the same procedure are rhinoplasty nasoplasty nasoseptopexy reconstruction of the nose and reconstruction of the nasal pyramid Some surgeons classify the same procedure under three different headings This is confusing to the operating room staff as well as to the assisting resident surgeons as a matter of fact in some hospitals the use of the word rhinoplasty" is forbidden—taboo In filling out charts, the surgeon must state he performed a nasal reconstruction when actually he had carried out a corrective rhinoplasty

Why should we at the present time conceal correction of external nasal deformities which are so frequently associated with internal ones under such a great variety of nomenclature? The term rhinoplasty' should be used today without verbal camouflage The patient understands this terminology much more than the phrase 'reconstruction of the nasal pyramid' Many a patient spontaneously declares that "I have had a rhinoplasty '

The term "rhinoplasty' is derived from the Greek "rhis'—nose and "plassein'—to form It is obvious then that a change in the form of the nose or any component part, constitutes a rhinoplasty It does not matter whether it is restorative corrective cosmetic, complete or incomplete In other words it is the correct term for the operation despite its questionable implications

It has been my policy when teaching corrective surgery of the external nose to use the term "rhinoplasty " I was greatly surprised to learn that physicians from different parts of the country objected to the use of this word The objection was not personal, but rather to the effect this would have on their medical colleagues It is obvious that in the various parts of the country they must conform to the usage of the term "rhinoplasty " It is a simple inclusive one Its ancient implications have been disspelled It has taken on a dignified and well merited status The art has reached a high degree of development The scientific journals welcome articles on rhinoplasty, and medical societies accept papers on rhinoplasty, indicating that the term is becoming a widely acceptable one

The basis of all corrective rhinoplastic procedures is preoperative diagnosis Analysis, relying on the rigid use of measurements, laws, and formulas, cannot supplant taste, judgment, and experience, essential in fine nasal plastic surgery As there are no two noses alike, no set of rules can be drafted that would fit all shapes of noses Certain principles when applied to every nose, will disclose its abnormalities The routine analysis considers forms, proportion, and harmony in relation of the nose to the rest of the facial features The fundamental artistic cannons must be fully understood by the rhinoplastic surgeon who is seeking a good esthetic as well as functional result

In planning to correct any nasal deformity, careful attention must also be given to the nasal septum which has a great bearing on the method of operation Is the septum a minor or major factor in the rhinoplasty? What should be the method of approach? The intranasal examination is supplemented by palpation of the septum This may reveal thickness and distortions

Planning begins with visual examination Is the correction feasible? Is the operation corrective or does it require much reconstruction, *e g* a harelip nose bifid nose, a dish face deformity? Has the operation limitations, *e g*, a short columella or an atrophic lobule, or very thick skin? The surgeon must plan to compensate, where to over or under correct

The visual examination is followed by palpation to determine the size, position, and character of the nasal bones, the form and position of the upper lateral cartilages, the texture of the skin, and shape of the lower lateral cartilages

The nasofrontal angle may not have a glabellar depression Palpation may reveal a thick procerus muscle A roentgenogram of this region is advisable to determine the depth of the bone and the relation to the frontal sinuses

Palpation at the base of the nose in case of a naso labial web may reveal a projecting nasal spine or the curved overhanging margin of the septal cartilage A recessed naso labial angle may be more retracted when pressure is made with the examiner's finger or instrument A retrusion caused by absence of septum contraindicates a complete transfixion on the other hand, restoration of the naso labial angle in the congenital variety requires a complete separation of the membranous septum from its septal attachment for mobilization necessary for reconstruction

Properly scaled photographs with a study of the nasal components in relation to the face forehead and chin are important for analysis diagnosis medicolegal and clinical records Each view lateral frontal nasal, may reveal a feature requiring correction Nasal deviations and irregularities are better shown in color photography

Photography is also important because it serves as a common meeting ground between the patient and the doctor By reversing the photo and placing it in an illuminating box the surgeon can easily draw the profile line which he considers esthetic This may or may not meet with the patient s approval and is a good way to avoid pitfalls of operating upon a neurotic individual who seeks a nose not compatible or attainable with his or her features

The diagnosis of a nose requiring revision of a rhinoplasty although subjected to analysis must be considered to be an exploratory operation Not until all of the parts are surgically exposed manipulated and reassembled can the surgeon make his precise decision for correction *e g* in many patients I found that complete osteotomies had not been performed

The wide nose creates problems because of the tendency to recurrence If it is present as a racial feature as in the Negro an implant or graft, as a rule is required without performing an osteotomy Otherwise if the lateral walls are of insufficient height to cover the vault one must decide whether an osteotomy and repositioning of the nasal processes of the maxillae has to be carried out prior to dorsal implantation

Width caused by excessive thickness of the nasal bones requires radical excision of these structures mesially and laterally I prefer to depress the nasal processes on mesial shifting after osteotomy in order that the septum perpendicular plate and nasal spine of the frontal project in the midline and become the summit of the nasal pyramid producing a narrow nose Ventral surfaces of a thick septum are thinned and redundant tissues such as mucous membranes lying between the bones and upper lateral cartilages are removed

Correction of a nasal deformity associated with a deviated septum frequently presents surgical problems These range from timing of the septal operation to the variety of the operation to be performed The questions which usually arise are Should septal correction be carried out prior during or after the rhinoplasty? If a deviated septum is present which operation should be performed to alleviate nasal obstruction and permit correct alignment of the nasal structures? Will a contemplated nasal profile and columella be placed in jeopardy with the production of a saddle of the upper cartilaginous vault a dropping of the lower cartilaginous vault or collapse of the entire nose?

Complete resection of the septum and replacing it in part based on a ' tie-in of the upper lateral cartilages with the septum has not proved reliable It was believed that the former structures alone could support the cartilaginous nasal dorsum because they were an integral part of the septum and were attached subjacently to the nasal bones and the frontal processes of the maxillae They were thus able to furnish adequate stability to maintain profile projection under static conditions Nevertheless removal of the cartilage and insertion of strips or resected cartilage did not prevent secondary cicatricial contraction and did not prevent an external dorsal depression or columellar retraction The cartilaginous implants between the mucoperichondrial layers frequently became twisted often to a degree that produced nasal obstruction

Subtotal or complete resection of septal cartilage with insertion of implants between the mucoperichondrial layers may be required in a depressed variety of septal deformity The sunken or fragmented septum cannot be shifted into its normal position and must be sacrificed As a rule however this kind of septal deflection is already accompanied by an external saddling deformity This would require insertion of dorsal grafts under any circumstances

The procedure I prefer restores the normal anatomic relationship of the deflected septum without or with minimal sacrifice of its structures The principles of the operation consist in mobilization of the septum to the midline by use of pedicle flaps of caudal septal sections, central replacement of posterior osseo-cartilaginous section resection, if necessary, of a small cartilaginous or bony bulge which can be obstructive No columellar retraction develops with this technique Straightening the caudal distortion, and thus elongating the septum, frequently corrects the columellar retraction Neither drooping of the nasal tip nor saddling occurs The septum gives the nose the same relative support after it heals as one that has not been operated upon It is, therefore, not so vulnerable to trauma in which septal components have been widely resected

Both sides of the caudal part as well as the remainder of the septum must be freed A unilateral or hemitransfixion does not liberate the distorted mucoperichondrial layers and thus prevents correct alignment of the replaced septal parts Postoperatively, healing is interfered with, owing to traction of the unelevated mucoperichondrium In consequence, there often is recurrence of the deformity This becomes obvious if one considers the pathogenesis of the caudal deformities Fracture of the cartilage occurs, and in the process of repair a fibrous invasion takes place between both sides of the mucoperichondrium and the cartilaginous fragments, and/or overriding fragments become intermingled with the mucoperichondrium

Experience has shown a rhinoplasty following a previously adequately corrected septum may also be followed by collapse of the nasal dorsum This occurs after osteotomy and meatal shifting of the nasal processes The remaining osseo-cartilaginous structures, despite supportive intranasal packing are unable to support the nasal dorsum The earlier rhinoplastic surgeons through sad experiences aware of this potential hazard, were wise to retain as much of the septum as possible in the carrying out of a concurrent rhinoplasty Obviously, there were many examples where nasal obstruction had to be corrected subsequently

The recent trend has been to perform a simultaneous rhinoplasty and submucous resection The septal correction whereby the structures are mobilized but are essentially intact is, in my opinion, the answer to the combined operation The upper lateral cartilages can be cut from the septum and appropriately trimmed

A combined rhinoplasty and submucous resection is also preferred by the patient for economic reasons for convenience and for time saving factors and the avoidance of two hospital admissions The rhinoplasty and an adequately performed septum operation can be concurrently accomplished with a good functional and assured esthetic result This is of benefit to the patient and of advantage to the surgeon

Certain nasal deformities require multiple procedures such as in children with saddle noses caused by trauma and/or infections resulting in loss of septal support Retrusion of the middle third of the face may form owing to lack of development Preserved cartilage implants reinserted until full nasal growth helps build up and raise the nose Harmless nonabsorbably foreign material may be more useful I inserted a large piece of ivory in a young patient whom I observed for ten years The original ivory implant was so adequate that at the age of adolescence, she refused further surgery and the nose was in good proportion to the rest of the face Today I would consider using an acrylic or polyethylene implant in a child in order to avoid many operations

Among the other conditions is the short columella This is essentially a skin condition and elongating the inadequate columellar skin without manifest scarring is difficult. After insertion of an implant on the columella reinsertion and another procedure to lengthen it may be necessary

The unusually small underdeveloped lobule often accompanied by flaccid crura is difficult to model despite the insertion of implants This is also a skin problem, as it cannot provide an adequate bed for the necessary implant. If the profile line cannot be lowered to meet the apex of the tip without producing a dorsal depression increase in size of the lobule can be attained only by an implant or graft, after reconstruction of the soft parts

Occasionally the surgeon attempts a rhinoplasty in which he removes the hump without modelling the tip or correcting the tip without modifying the osseous or upper cartilaginous vaults A non satisfactory result will require a revision with insertion of the omitted operative step Flaring alae not corrected at the time of the rhinoplasty may require correction at a later date.

It is well known that among the other nasal conditions frequently requiring more than one operation are the harelip nose nasal atresia dish face deformity and bifid nose

Healing plays an esssential part in the final rhinoplastic result. It is common knowledge that a nose which appears perfect at the end of a rhinoplasty or when the external dressing is removed may assume an undesirable form as early as the tenth post-operative day One may be asked What is the nature of this process in tissue repair which militates against the welfare of the patient? Rhinoplastic surgeons have become aware of the risks of oily thick and pre-acne rosacea varieties of the skin nevertheless sooner or later the surgeon operates upon such patient and the skin behaves badly as healing takes place producing an unsatisfactory esthetic result Ideal situations for rhinoplasty are not always encountered

The time has come for the otolaryngologist interested in rhinoplastic surgery not to confine his thoughts solely to the technique or diagnosis If he is to continue to advance rhinoplasty he must undertake research in the process of skin healing for on this hinges the more acceptable results

The panelists have been using the word crutch' To attain recognition of his position in rhinoplasty the otolaryngologist has had to pave the way by exploiting various representations like nasal physiology for example The time is approphiate for the otolaryngologist to refrain from hiding behind subterfuge of disturbed nasal physiology as the single indication for his interest in rhinoplasty It is generally conceded that the nasal septum requires correction in from 60 to 70 per cent of all rhinoplasties rhinologic training the skillful use of the head mirror or headlight intranasal tools and correct manipulation are the *sine qua non* for an overall cosmetic rhinoplasty The time has come for the rhinologist to declare that he is rightfully entitled to correct a nasal deformity for cosmetic and psychologic reasons It should be made clear that a rhinoplasty is not performed solely for the preservation and restoration of nasal function If a functional cause exists this of course adds to the necessity for operative intervention

Finally it is my belief that too much emphasis has been placed on the ill-effects of intranasal incisions and preservation of the valve areas Patients complain of nasal obstruction following a rhinoplasty when excessive vestibular skin has been sacrificed causing synechase between the lateral crura and septum Various degrees of alar collapse causing disturbance in breathing accompany the pinched tip Although the septum and upper lateral cartilages caudally form the so-called valve' severance of these structures in a rhinoplasty is not followed by disturbed physiology after reattachment on healing whether the excessive cartilage is removed *in toto* or submucosally Evidently, the scar tissue formed at the valve region does not appear to interfere with its presumptive function It is only when the redundant protruding upper lateral cartilage is not removed that it acts mechanically to obstruct the airway producing nasal obstruction With the removal of the excessive projection, adequate airway is restored The important structure in rhinoplasty requiring preservation is the membranous septum Sacrifice may cause columellar retraction and loss of service should a strut be required

Arthur W Proetz, M D, (St Louis Mo) I have listened with great interest and attention to the presentations of my colleagues and have been at some pains to read as much of their writings as I could find since my assignment was directed to the physiological aspects of the subject and not too much has been said on that score during the preceding discussions

I have also brought along a specimen Forty five years ago this nose had a terrific spur removed from its septum through a submucous resection, and parts of both inferior turbinates were trimmed away with scissors Before and after the operation the ridge pole ran in two directions and ended in an unsightly lump—and still does Whether this deformity blighted its owner with an inferiority complex I must leave to you Physiologically it is perfect

There has been much controversy over the propriety of combined operations on the nose, and before launching on my theme I should like to contribute one or two views from the sidelines

1 If a nasal inlet needs widening or narrowing, or the septum straightening, and besides this the profile needs fixing—if in short, combined operations are indicated, it seems axiomatic that they should be done at one time and by one operator If done in two stages, the second operator is almost bound to be hampered by scar tissue and by someone else s leavings which are not part of his plan, and the patient suffers double pain and expense

2 If Dr John Smith is a competent surgeon familiar with the specific anatomy, physiology, pathology and surgery of all the parts concerned and has the necessary judgment, based on experience then, and only then, he is the man for the job All other qualifications combined cannot compensate for the lack of any one of these After that, whether Dr Smith is called a plastic surgeon or a rhinologist or a proctologist, could not matter less to the patient or his tissues Jurisdictional disputes are as transparently commercial in this field as they are in others

3 Let us honestly face the distinction between physiology and cosmetology and never not ever confuse the two for the purpose of making any surgeon or any operation seem more respectable or more attractive or for any other reason

And so to work

With the surgical procedures discussed here and their purpose, I have nothing but agreement and approval in particular with some of Dr Owens' straightforward remarks within the limits of my experience On physiological grounds I fear we part In all frankness I cannot get away from the feeling that there is a good deal of groping for some new scientific background to fit surgical procedures already current which to me has all the disadvantages of walking backward and has in the past led to too many untenable hypotheses

We all agree that as stated a nose that isn t working needs fixing

As to what to do and how far to go Dr Ogura laments the lack of any concise standardizing measurements such as we have for sight and hearing I doubt that they would be of much help if we had them for as Dr Ogura himself observes the two cases are scarcely parellel Only the olfactory portion of the nose is a special sense organ like the eye and the ear and the sense of smell has not been brought up in this discussion We are dealing with something much simpler and less critical I have no doubt that anthropologists have scientifically measured and classified our hands and feet (they come in all sizes shapes and colors) but while anthropological indices are helpful in such projects as tracing our remote ancestors we do not use them to find out how we all run or dance or write or who can stretch an octave It simply isn t that complicated

We know that one asymmetry here is often compensated by another asymmetry there and put together they make a healthy nose That also is not too difficult to determine

Although the shape of the nostril is less important than its size and direction even in the last much latitude is permissible and minor variations in the angle of tilt are of small consequence—physiologically that is

From the standpoint of warming and humidification the vestibule is practically negligible being too small and made of the wrong things

The submucous resection of Killian and Freer has been mentioned as a satisfactory procedure when performed in certain types of deviated and obstructed septums" but fears are expressed regarding cosmetic complications perforations saddling and retracted columellae as though these were common accidents In incompetent hands they may be but that is true of any operation Perforations we have all had most of them negligible unless they whistled in which case they were promptly repaired

So long as I can remember rhinologists worthy of the name have diversified the standard procedures to fit cases and have variously revised faulty passages without ado It is my observation that those who have had many unsatisfactory results from septal surgery have not been very good at it. While certainly not implying that complaints from the patient are the only justification for operating I do not quite follow Dr Ogura when he says (I copy him verbatim) "The feeling seems to be prevalent that a patient with a deviated septum or in another instance with a hump physiologic needs are in order to justify the performance of a rhinoplasty While in some instances this is necessary in many other instances this will not be true Unless Dr Ogura is talking now of pure cosmetics I wonder what these many other instances could be

I cannot agree that as has been stated this morning our knowledge of the exact function of the nose is unduly limited Merely because a function is simple we need not feel obliged to postulate something more complicated and as yet unknown I would say that our present knowledge serves us very well and in the same breath enthusiastically encourages new discoveries and conceptions but I would insist that they rest upon firm scientific foundations and I should prefer that they were practical

On last Friday I had a letter from Dr Williams saying that 'for reasons of time limitation he had decided to delete four pages of his presentation By some unfortunate coincidence these were the four pages dealing with the physiological aspects which I am here to discuss

As however they do constitute some of his thinking and that of his group and I do have the time I should like to quote some of the material he was obliged to skip and to bring it up for discussion since I think it too important to overlook.

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I cannot agree that, as has been stated this morning our knowledge of the exact function of the nose is unduly limited Merely because a func tion is simple we need not feel obliged to postulate something more complicated and as yet unknown I would say that our present knowledge serves us very well and in the same breath enthusiastically encourages new discoveries and conceptions but I would insist that they rest upon firm scientific foundations and I should prefer that they were practical

On last Friday I had a letter from Dr Williams saying that for reasons of time limitation he had decided to delete four pages of his presentation By some unfortunate coincidence these were the four pages dealing with the physiological aspects which I am here to discuss

As however they do constitute some of his thinking and that of his group and I do have the time I should like to quote some of the material he was obliged to skip and to bring it up for discussion since I think it too important to overlook of these structures in a rhinoplasty is not followed by disturbed physiology after reattachment on healing whether the excessive cartilage is removed *in toto* or submucosally. Evidently, the scar tissue formed at the valve region does not appear to interfere with its presumptive function. It is only when the redundant protruding upper lateral cartilage is not removed that it acts mechanically to obstruct the airway producing nasal obstruction. With the removal of the excessive projection, adequate airway is restored. The important structure in rhinoplasty requiring preservation is the membranous septum. Sacrifice may cause columellar retraction and loss of service should a strut be required.

Arthur W. Proetz, M.D., (St. Louis, Mo.): I have listened with great interest and attention to the presentations of my colleagues and have been at some pains to read as much of their writings as I could find since my assignment was directed to the physiological aspects of the subject and not too much has been said on that score during the preceding discussions.

I have also brought along a specimen. Forty-five years ago this nose had a terrific spur removed from its septum, through a submucous resection, and parts of both inferior turbinates were trimmed away with scissors. Before and after the operation the ridgepole ran in two directions and ended in an unsightly lump—and still does. Whether this deformity blighted its owner with an inferiority complex I must leave to you. Physiologically it is perfect.

There has been much controversy over the propriety of combined operations on the nose, and before launching on my theme, I should like to contribute one or two views from the sidelines.

1. If a nasal inlet needs widening or narrowing, or the septum straightening, and besides this the profile needs fixing—if, in short, combined operations are indicated, it seems axiomatic that they should be done at one time and by one operator. If done in two stages, the second operator is almost bound to be hampered by scar tissue and by someone else's leavings which are not part of his plan, and the patient suffers double pain and expense.

2. If Dr. John Smith is a competent surgeon familiar with the specific anatomy, physiology, pathology and surgery of all the parts concerned and has the necessary judgment based on experience then and only then, he is the man for the job. All other qualifications combined cannot compensate for the lack of any one of these. After that, whether Dr. Smith is called a plastic surgeon, or a rhinologist, or a proctologist could not matter less to the patient or his tissues. Jurisdictional disputes are as transparently commercial in this field as they are in others.

3. Let us honestly face the distinction between physiology and cosmetology and never, not ever confuse the two for the purpose of making any surgeon or any operation seem more respectable or more attractive or for any other reason.

And so to work.

With the surgical procedures discussed here and their purpose I have nothing but agreement and approval in particular with some of Dr. Owens' straightforward remarks within the limits of my experience. On physiological grounds I fear we part. In all frankness I cannot get away from the feeling that there is a good deal of groping for some new scientific background to fit surgical procedures already current which to me has all the disadvantages of walking backward and has in the past led to too many untenable hypotheses.

We all agree that as stated, a nose that isn't working needs fixing which is the vestibule has obsolutely nothing to do with it It could be replaced by a little round pipe or big square tank or a slide trombone So long as the hole is pointed in the right direction, it does not make a bit of difference what comes before To point the airstream below the rostrum of the sphenoid a major distortion would be required a flattened nose, a saddle nose, or something else that is pretty easily diagnosed If the jet veers to one side enough to create a dry spot, and the dry spot can be shown to make trouble it should be straightened I believe it is as simple as that.

SEVENTH INTERNATIONAL CONGRESS OF BRONCHOESOPHAGOLOGY

The Seventh International Congress of Bronchoesophagology will be held at Kyoto (Japan) University, September 12-14, 1958, under the direction of Prof Mituharu Goto, M D, Otorhinolaryngological Clinic, Kyoto University Hospital, Kyoto, Japan

A registration fee of $25 00 U S.A. will be charged all physicians and a fee of $10 00 for wives or non-medical guests Registered members are admitted free to banquet, receptions and sightseeing tours

If I misquote Dr Williams in anything, I hope he will stop me

Dr Williams stated 'We are aware of variations which in one person may produce symptoms, in another they may not, and on clinical examination very little difference can be observed in the structures of the nose" Again, I wonder whether I interpret him correctly as proposing surgery on these symptomless cases when he continues "We do feel, however, that there should be a proper relationship of the vestibule to the os internum of the nose, and also a proper relationship of the lateral walls of the nose to the nasal septum" I hope not, since he admits in his next sentence that "it is difficult to put into figures just what this relationship is" and that "the various indices, such as the choanal index, and the clinical nasal index, as well as the X ray nasal index gives us figures which are only relative"

I cannot say whether I agree with some of the other statements or not, since I do not understand just what they are meant to imply For eyample "When the nostrils are round and wide, usually the os internum is similar and an excessive amount of space is usually present between the lateral nasal wall and the nasal septum" Excessive by what standards? Injurious? Symptom producing? Or merely larger than *some ethnological mean?* "We are particularly concerned with injuries to the Caucasian nose which may simulate, in many respects a nose of different ethnic origin" Does that mean that if my nose had the characteristics of a negroid nose it would not serve me as well as it would my African friend next door? Presumably it is meant that such a nose would be disproportionate to the rest of my Teutonic cranium and that its function would thereby be upset This could be sometimes, but the ethnical reference seems remote Dr Williams adds "A study of embryology is quite revealing in this respect," but he does not tell us what it reveals, or what is its surgical importance

"Neither can anthropologic considerations be ignored," but he does ignore them in his discussion and it would have been interesting to know what they are and what they show

Still on the physiology of the nostrils, I can summarize only by saying that I regard it as much more definite and much simpler than it is being painted To put it in one sentence "The function of the nostrils and the pyramid is to pass an adequate amount of air in a generally upward direction into the nose' I say 'generally" upward because the angle is not very critical

There have been recurring refrences to "philosophies, concepts, indices, ethnics" "the disturbance of septal totality" and so on It all sounds very profound and very scientific, and very new, frankly I cannot see it as being very much of any of these When the fury of the tempest dies away it all ends up in a teapot and the teapot is a familiar piece of antique crockery described by Charles Bell a century ago and by others since

The teapot also is a fine example of the vestibule and how it works If you will permit me, I will make a sketch of it (drawing on the board) The teapot is a hollow object spouting a jet The nature of this jet is determined by the size and shape and direction of the opening at the tip and by nothing else The teapot represents the vestibule and the opening represents what one has lately been calling the os internum which by the way my dictionary defines as "the uterine end of an oviduct"

So long as the jet is directed *generally* upward things are all right. It can be almost anywhere between straight up and straight back so long as it does not fall below the rostrum of the sphenoid and bypass the functional part of the nose altogether The size and shape of this teapot, which is the vestibule has absolutely nothing to do with it It could be replaced by a little round pipe or big square tank or a slide trombone So long as the hole is pointed in the right direction it does not make a bit of difference what comes before To point the airstream below the rostrum of the sphenoid a major distortion would be required a flattened nose a saddle nose or something else that is pretty easily diagnosed If the jet veers to one side enough to create a dry spot, and the dry spot can be shown to make trouble it should be straightened I believe it is as simple as that.

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SYMPOSIUM

MODERN CRITERIA FOR DIAGNOSIS AND THERAPY OF MALIGNANT DISEASE IN THE UPPER RESPIRATORY TRACT

MODERATOR

JEROME A HILGER, M D , St Paul, Minn

PANEL

HAROLD G TABB, M D , New Orleans, La
WALTER P WORK, M D , San Francisco, Calif
JOHN J CONLEY, M D , New York, N Y

CANCER OF THE NASOPHARYNX AND OROPHARYNX

JEROME A HILGER, M D
St Paul, Minn

An enlarged lymph node in the cervical area is frequently a metastasis from a quiet primary carcinoma The diagnosis is properly made by identifying the primary lesion, not by removing or sampling the node If thorough visual and tactile search reveals no primary, multiple biopsies from the innocent appearing nasopharynx may reveal it In addition a submental-occipital view of the skull base should be obtained An infiltration arising from the lateral nasopharynx can produce distinctive alterations in this view, though nothing is seen, felt or obtained by biopsy in the nasopharynx[1] In any case, this sequence properly precedes direct approach to the nodal enlargement

When the latter is necessary the use of the needle biopsy

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offers many advantages over node excision A new needle has recently been described for this purpose[2]

CANCER OF THE NASOPHARYNX

Cancer of the nasopharynx constitutes 0 4 per cent of all cancer in occidental countries,[3] it constitutes 5 per cent of cancer in China[4] The reason for the difference is not known In order of frequency the symptoms of cancer of the nasopharynx are *1* Enlarged gland or glands in the neck, *2* nasal symptoms, obstruction or epistaxis, *3* Vth nerve pain (in clinical analysis of this symptom a routine submental-occipital X-ray view is a useful addition to clinical examination), *4* signs of auditory tubal obstruction, and, *5* paralysis of cranial nerves other than the Vth cranial nerve

In 50 per cent of cancers of the nasopharynx a metastatic node is the first evidence of disease. In 70 to 80 per cent metastatic nodes are present at the time of diagnosis A high posterior cervical triangle node is the most frequent individual nodal involvement[5]

The average patient waits three months after the appearance of first symptoms of cancer of the nasopharynx before consulting a doctor, the correct diagnosis is not made for an additional four months in the average case, and proper therapy is not applied to the average cancer of the nasopharynx until ten months have elapsed from initial symptoms[6] While 10 to 15 per cent of cases present cranial nerve paralyses as the first symptom of disease, nerve involvement has increased to 20 to 25 per cent of all cases by the time correct treatment is initiated[3]

Lack of microscopic differentiation of a high percentage of nasopharyngeal cancers has resulted in varied pathologic classifications Division into squamous cell epitheliomas, lymphoepitheliomas, and lymphosarcomas delineates treatment and prognosis satisfactorily The above order is that of frequency of occurrence[1] Favorable prognosis, however, is in reverse order Thirty to 50 per cent of lymphosarcomata can be expected to be well five years after treatment This is reduced to 25 per cent with lymphoepitheliomas and to 15 per cent with squamous cell carcinoma [1,5,7]

Cranial nerve involvement, decalcification of the skull base, and presence of metastases are ominous prognostic signs in a given case [7]

Cancer of the nasopharynx cannot be cured by surgical methods Principal dependence is on radiation therapy There is a wide variance in methods of applying it

Since diagnosis centers on the surgical techniques of the otolaryngologist he frequently maintains an interest at the therapy level This is usually expressed in terms of surgical exposure of the tumor, as with palatal fenestration[8] or partial septectomy,[9] in fulguration of the tumor, or in techniques of intracavitary radiant applicators [10,11] The primary tumor that persists to kill the patient, however, is that cell most remote from the cavity and from fulguration and local radiant sources For more complete blanketing and homogeneous distribution through the tumor zone it is probably true that external, multiple-port irradiation most nearly fulfills the ideal [7,12,13] Combinations of intracavitary and external ray sources have no advantage and some disadvantage to deliverance of the total dose by multiple external ports as the primary treatment The intracavitary techniques are most applicable for tumor persistence where the skin will tolerate no further external irradiation [9]

Because of skeletal parts that must be traversed by the beam, the increased penetration of the Gamma rays of cobalt 60 are preferable for external treatment to the radiations of the more universally available 250 kilovolt equipment

Since 70 to 80 per cent of cancers of the nasopharynx have or develop cervical nodal metastases treatment of the anterior and posterior cervical triangles should be included with treatment of the primary Because over 30 per cent of cases metastasize eventually to the contralateral side also, the supra-omohyoid cervical lymphatics should be included on that side If metastasis is already present on this second side the field should be extended to the clavicle [13]

Total irradiation dosage with any technique is a factor of individual response Here the real skill of the radiation therapist becomes apparent The otolaryngologist serves best who is most critical in his selection of a therapist

The usefulness of neck dissection for persistent metastatic node involvement has to be analyzed in the light of two considerations *1* The uncertainty of primary control, *2* the unresectable lateral pharyngeal node, the highest node in the chain A case in this predicament requires the application of the most thorough irradiation effort to the metastasis before surgical resort[14 15]

Persistence of primary tumor, as evidenced by reappearance after a quiet interval, should be pursued by additional irradiation The technique may have to be modified by skin tolerance This may be carried to a third and a fourth series Thus, though "cure" and "survival" are not synonymous, the latter is desirable to the limit of a reasonably comfortable life In one small series the three year survival was increased from 21 per cent to 57 per cent by these persistent tactics[16]

CARCINOMA OF THE OROPHARYNX

The oropharynx is that anatomic segment extending from the arch of the atlas to the hyoid bone Its anterior limit is the buccopharyngeal sphincter comprised of anterior faucial pillars and soft palate, and the base of the tongue to which the sphincter closes Malignancy in the area occurs principally as squamous carcinoma of the soft palate, squamous carcinoma, lymphoepithelioma, and lymphosarcoma of the tonsil, squamous carcinoma, lymphoepithelioma, and lymphosarcoma of the lingual base, and squamous carcinoma of the linguo-tonsillar and glosso-pharyngeal sulcus and vallecula Malignancy of the posterior oropharyngeal wall and of the lateral wall posterior to the posterior faucial pillar is uncommon

Cancer of the Soft Palate

Carcinoma of the soft palate is typically squamous and differentiated True primary involvement, as distinguished from extension of tonsillar cancer is not common Metastasis, when it occurs, is to the upper deep cervical nodes External irradiation therapy may be combined with irradiation through the open mouth Neck dissection should be done for uncontrolled metastases if the primary appears controlled The *five-year control rate through these treatment methods* approximates 25 per cent

Cancer of the Tonsil

Cancer of the tonsil comprises 2 to 3 per cent of all cancer Only cancer of the laryngopharynx is more common in the upper respiratory tract Lymphosarcoma occurs on an average at an earlier age than does lymphepithelioma or squamous carcinoma The latter occurs preponderantly (nine to one) in men It usually spreads quite rapidly to the soft palate, the anterior pillar, or the linguo-tonsillar sulcus Metastasis to the upper deep cervical lymph node is usually present It may be the outstanding first symptom with an inconspicuous primary The latter may be palpable in the tonsil when it is not actually visible A punch biopsy of the suspected area is a sounder approach to diagnosis than is enucleation of the tonsil The lymphatic flow from the malignant area will increase in direct proportion to the trauma and extent of the biopsy procedure

As a method of primary treatment surgery has no place in the treatment of tonsillar cancer External irradiation is the best therapy Bilateral fields include the immediate upper deep cervical lymphatic area The best assumption is that these are involved metastatically even in the absence of clinical evidence The metastatic disease is more uniformly responsive in tonsillar cancer than in other oropharyngeal cancers This is the most important part of the disease, and treatment should be carried to full dosage even though the nodes disappear early in the course of treatment Neck dissection is indicated for the infrequent case where there is primary control with persistent metastases The dissection must be carried well above the level of the digastric muscle

One of the most distressing complications of the irradiation treatment of tonsillar cancer is mandibular radionecrosis It may develop years later The usual immediate cause is extension of infection from carious teeth and peridental infection into the partially devitalized bone This can be avoided by the removal of the teeth before therapy is begun

The presence of metastases in cancer of the tonsil has an important bearing on prognosis In one series of 160 patients metastases were present in three-fourths of the cases In 11 per cent these were bilateral The five-year control rate in the absence of metastases was 20 per cent In those cases presenting unilateral metastases it was 4 per cent When bilateral metastases were initially present the salvage at the end of five years was zero [17]

The best prognosis in tonsillar cancer is in the lymphosarcomata The outlook is approximately twice as favorable as with squamous cancer, 30 to 40 per cent five year control as compared with 15 to 20 per cent The lymphoepitheliomata lie somewhere between

Cancer of the Lingual Base

That portion of the tongue posterior to the circumvallate papillae has well known histologic differences from the mobile anterior lingual two-thirds Cancer involves the posterior area less frequently, in a ratio of five cancers in the anterior segment to one posteriorly Cancer in the lingual base is a disease primarily of males Squamous cancers far outnumber the lymphoepitheliomata and lymphosarcomata Upper deep cervical node metastases (at and below the level of the hyoid horn) are the rule in all three types, 80 to 90 per cent have metastases The spread is often bilateral, in one-third if the primary is confined to one side of the base, and in two-thirds when the primary is on both sides of the midline

External irradiation is easily applicable to the primary, and necessarily crosses both lateral lymphatic zones Special applications of radium needles and radon seeds have been advocated,[18] but on theoretical grounds lack homogeneity and add nothing in total dose to what is accomplished through external irradiation Unfortunately, in the squamous cancers five-year control of the disease is obtainable in fewer than 10 per cent of cases by either method Again, the results are twice as good with lymphoepithelioma and lymphosarcoma

Surgical resection of the primary area is not feasible in cancer of the lingual base Since X-ray sterilization of the primary occurs only infrequently, there are few instances where neck dissection for the uncontrolled metastatic bed is indicated in this miserable disease

Cancer of the Linguo-Tonsillar and Glossopharyngeal Sulcus and Vallecula

Occurring, as they do, in a natural anatomic fold these tumors can be overlooked with the flashlight-tongue blade routine of the casual examiner It will be a real accomplishment when the otolaryngologists indoctrinate their medical conferees in the simple routine of mirror examination and forefinger palpation of the oropharyngeal area Sulcus cancer can be deeply infiltrating and present only a fissure-like ulcer at the surface [19, 20]

As with all of the oropharyngeal cancers, the sheltering effect of the mandible and the proximity of the cartilaginous larynx demand careful external irradiation of sulcus and vallecular cancer Penetrating Gamma irradiation, as with Cobalt 60 on theoretical grounds, offers distinct advantages [21, 22, 23] Tumor residuum is treated by some with implantation of radon emanation seeds Special techniques with radium needles and emanation seeds have their greatest usefulness where further external irradiation for persistent tumor is not possible because skin tolerance would be exceeded

Surgery is useful for persistent metastasis if the primary is controlled This combination of circumstances is not common In addition the metastatic involvement has a way of infiltrating the carotid sheath In the presence of uncertain primary control, the prospect of carotid resection *en bloc* is discouraging to temperate surgical minds, indeed, it is a rare cancer in this area that lends itself to surgery for the primary or the secondary Sulcus tumors do not have as favorable outlook for cure as does tonsillar cancer As a group, they do, however, have a better outlook than cancer of the lingual base

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The early symptoms and signs are in no way indicative of the lethal disease which is causing them Unilateral epistaxis, nasal obstructions and discharges, and widening of the nasal bridge are by no means uncommon in nonmalignant disease Even when the symptoms and signs become more severe, pain radiating to the teeth, the cheek and the orbit, ocular proptosis, and tender swellings of the palate and antral area, the physician who does not possess a healthy curiosity will not undertake the appropriate diagnostic studies

Malignant disease of the nasal cavity and paranasal sinuses must be constantly suspected as an explanation of such symptoms and signs as I have just listed It must be considered to be present until it is proved not to be, under the following conditions

1 When unilateral masses are present in the nose

2 When polypoid masses have been present in the nose and sinuses for a considerable time, and their removal is attended with abnormally free bleeding

3 When there is prolonged unilateral nasal blockage, with a blood-tinged purulent discharge

4 When the complaint of pain in the cheek or upper teeth is disproportionate to the clinical findings

5 When a purulent sinus infection fails to respond to adequate treatment within a reasonable period of time

6 When unilateral swelling and tenderness occur in the nasal area

These symptoms and findings require a diagnostic survey, in which a careful local examination and nasopharyngoscopy are the first steps

Roentgenologic examination comes next The positive signs include opacity of the nasal cavity, irregularity of the soft

THE NASAL CAVITY AND PARANASAL SINUSES*†

HAROLD G TABB, M D,

New Orleans, La

A discussion of cancer of the nasal cavity and paranasal sinuses which does not begin with an admission of the distressing fact that the results of treatment are generally poor, is simply not realistic One reason for the poor results is anatomic, the structural continuity of the area is an invitation to rapid spread of any disease process Another reason is clinical, the usual textbook description, though unfortunately it very often fits the state of the patient when he is first seen, is the picture of advanced disease, not of early, curable disease Diagnosis will be delayed and treatment will be ineffective until this mistaken concept is overturned

Patients are generally late in seeking medical advice A delay of three months is about average, but a delay of six to nine months is not at all unusual, and every series contains cases in which the delay is a year or more One reason why patients delay is that the symptoms of cancer in these areas are often the symptoms of diseases which they have had for months or years The etiology of malignant disease of the nasal cavity and paranasal sinuses is still unsettled, but in many instances it is related to such conditions as chronic sinusitis, allergies of various kinds, polypi, and nasal obstructions in which there is interference with proper ventilation and drainage, and to which the patients have become accustomed

Another reason why patients are seen late is that the physicians and dentists, whom they have first consulted, have treated them on the basis of the symptoms they presented, without investigating what underlies them Otolaryngologists themselves are often at fault We plead for the early refer-

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†From the Department of Otolaryngology Tulane University of Louisiana School of Medicine

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by hospital blood banks, and the availability of wide-spectrum antibiotics

The Weber-Fergusson incision is used to expose the facial surface of the maxilla, and the entire maxillary bone, with the maxillary sinus, ethmoids, and orbital contents, is removed *en bloc* To accomplish this, the palate must be split in the midline and the maxilla and portions of the zygoma and ethmoid bones separated from their attachments The sphenoidal, frontal, and posterior ethmoids are curetted and fulgurated, as are any other suspicious areas The cribriform plate may be removed and the underlying dura cauterized, to care for possible extensions The eye is always included in the dissection unless an obviously clear margin of normal tissue can be demonstrated between it and the lesion If there is any doubt, the eye must be sacrificed

Since cancer of the nose and sinuses is characteristically late in metastasizing, radical neck dissection, although it can be performed with maxillectomy, is usually deferred Often it is not employed until the indication for it becomes evident

During the operation, the entire cavity is irrigated with a cancerocidal solution, to reduce the number of viable cancer cells in the wound washings When the tumor is highly malignant, it is well to follow its surgical removal with some appropriate chemotherapeutic agent Perfusion techniques, which have given very promising results in some regions of the body, for anatomic and other reasons do not seem applicable at this time to cancer of the nasal cavity and paranasal sinuses

The solution to this particular problem lies with the general practitioner, the dentist, and sometimes the ophthalmologist even more than with the otolaryngologist It is our duty to be eternally on guard, ourselves, and to acquaint those who are not practicing this specialty with the real facts of this disease, otherwise, many a patient will continue to lose his only chance of life Until diagnosis is achieved earlier, radical surgery followed by maximal radiation, which, given a fair chance, *can* control the disease, will often prove palliative rather than curative, and the results will be poor as well as tissues, and bony destruction Cytologic examination by the Papanicolaou technique is valuable when it is positive, but useless and possibly misleading when it is negative The same holds for aspiration biopsy

Even frozen section has a margin of error, yet there is no room for error when mutilating surgery, such as is necessary in this variety of cancer, must be undertaken If repeated biopsies are negative and the suspicion of cancer still persists, an exploratory procedure is warranted The pathologist must be supplied with a representative section of tissue, and he must be given ample time to study it

These facts may be elementary, but they constitute the background of successful therapy Until the disease is recognized, treatment will not be instituted Unless the disease is recognized early, the most potentially useful treatment will be useless

Irradiation, which was formerly generally employed, was used, as Frazell has well put it, more by default than by any proved superiority of results, in fact, it has decided disadvantages, including severe ocular complications It may also cause infection and prolonged disability because of the edematous obstruction of normal drainage channels by infected and necrotic cancer tissue The corrective procedures required when this happens are often of such magnitude that radical surgery might as well have been employed to start with

It is true that with the advent of supervoltage therapy, irradiation promises for the future better results with fewer disastrous side-effects That day, however, has not yet arrived At the present time, the optimum treatment is radical surgery combined with maximum doses of radiation by both the intracavitary and external techniques

The surgery must be radical Anything less than wide exposure and *en bloc* removal of the involved tissues is inadequate treatment Surgery of such magnitude is now practical because of improved techniques of anesthesia, including hypotension, the liberal use of whole blood provided exists in any part of the larynx or hypopharynx and whether there is direct extension or metastases Other characteristics such as size, presence of edema, surface growth, or deep ulceration may be of further assistance in classification

III Diagnosis

The diagnosis of cancer in the areas under discussion can usually be made by biopsy and microscopic examination of the tissue Other aids in establishing diagnosis are, Papanicolaou's stains of extruded cells, tomography, contrast media Roentgen studies and palpation Further surgical procedures may be required for correct diagnosis such as repeated biopsies and thyrotomy If it is necessary to resort to the latter, the operating room should be set up and the surgeon prepared to carry out definitive surgical treatment after the diagnosis is established by microscopic frozen sections

In our experience, over 99 per cent of the cancerous lesions in this area have been of the squamous cell variety Generally, if the site of origin of the lesion is other than the true vocal cords, one may expect to find the neoplasm less well differentiated microscopically According to Broder's classification, most cordal squamous cell carcinomas are of Grades I and II Only recently, we have seen a case with a small cancer of the true vocal cord which was remarkably anaplastic in its growth patterns, and was considered by our pathologist to be Grade IV

IV Treatment

Surgery and radiation therapy are the only two forms of therapy available today for the treatment of patients with cancer of the larynx In no sense of the word, should these two methods of treatment be competitive, but should be closely integrated even in the same patient when indicated

Illustrative cases with various types of lesions will be presented

Patients with early Stage I cordal squamous cell carcinomas should be treated by peroral removal and fulguration, rather than with radiation therapy mutilating With earlier diagnosis and correctly applied therapy, the proportion of five-year results will readily be doubled

CANCER OF THE LARYNX AND PHARYNX DIAGNOSIS AND TREATMENT *

WALTER P WORK, M D ,

San Francisco, Calif

I *Introduction*

My part of the symposium is to discuss the diagnosis and treatment of squamous cell carcinoma of the larynx and hypopharynx I can only outline our experiences with this disease in the time allocated

II *Classification*

We classify cancer of the larynx and the surrounding anatomical areas according to the International Radiological Congress' proposals made in Copenhagen in 1953 Of the many proposals for classifying cancerous lesions of the larynx and hypopharynx, the above appears to be workable and useful Frequently, clinicians will make modifications in any classification according to their needs and to the needs of their patients

Cordal, supraglottic, subglottic, hypopharyngeal and postcricoid are descriptive terms used for anatomical areas in which lesions are placed Often the dividing line between these areas is not sharply defined, and in some patients it is difficult to determine the true anatomical site of the origin of the lesion Lesions are further graded in Stages I to IV Such staging is an aid to the clinician in planning therapy and evaluating results The staging of lesions by the clinician is an attempt to determine whether impairment of function

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the initial surgery, so that contralateral block dissection may be carried out as early as possible if nodes appear

Advanced Stage II supraglottic lesions in the region of the petiolus of the epiglottis are difficult to treat by any method These lesions must be considered as potentially metastasizing to the lymph nodes in both sides of the neck Widefield laryngectomy plus initial unilateral block dissection of the neck, and later block dissection of the contralateral side are frequently indicated This is particularly true when microscopic lymph nodes are found in the original operative specimen Patients with Stage II lesions on the lateral surface of the epiglottis and upper aryepiglottic fold areas, must be considered candidates for similar surgical treatment Cases with Stage II lesions of the aryepiglottic fold proper extending into the false cord and pyriform sinus must be considered for similar treatment This is true also for patients with Stage II lesions in the arytenoid area All patients with Stage III lesions in those areas should be treated likewise, providing the lymph node metastases are resectable

Patients with lesions in other portions of the epiglottis, not noted above, should be treated surgically Cases of cancer of the free upper surface of the epiglottis suitable for peroral removal are rare indeed Such lesions would fall into Stage I, and we have seen none in our series of cases Likewise, patients with lesions in this area, early Stage II, suitable for transhyoid resection are rare We have seen one patient who had an extensive Stage II cancer in this area which was treated by radiation therapy in 1950 In 1956 there was a recurrence on the free upper border of the epiglottis which was removed surgically by the transhyoid approach

Patients with lesions of the entire epiglottis are usually seen in Stages II and III Their prognosis is poor, even with extensive surgery or radiation therapy, or with both Patients with early Stage II lesions of the central posterior surface of the epiglottis should be treated by widefield laryngectomy Unilateral lesions of the epiglottis are most often seen in late Stages II or III, and require widefield laryngectomy in combination with unilateral or bilateral block dissection

Cordal lesions, Stage I, slightly more advanced than in the above cases, are ideal for either radiation therapy or laryngofissure I cannot specifically recommend surgery or radiation therapy for a given patient since many factors, such as age of patient, general health, etc, will influence the doctor's choice of treatment Patients with carcinomas *in situ* localized to a small area of the true vocal cord should be treated surgically

If we consider more extensive lesions of the vocal cord, such as a cordal lesion, Stage II, where function is impaired and there are no palpable cervical lymph nodes, surgery should be considered in lieu of radiation therapy The Som[1] operation for posterior one-third cordal lesions, and hemilaryngectomy or the modification of this procedure with primary skin graft, as advocated by Figi[2] should be considered

In patients who have a cordal lesion, Stage II, (even with both vocal cords involved), with marked limitation of motion and the cancer is still confined within the cartilaginous larynx, the procedure of choice is widefield laryngectomy Patients with late Stage II and III cordal lesions will require widefield laryngectomy and simultaneous unilateral block dissection Many of these cases with advanced lesions will have ventricular or subglottic extension or both Cancer arising on both vocal cords may be so extensive that a later contralateral block dissection may be necessary if metastatic nodes appear

Patients with supraglottic squamous cell carcinoma are usually first seen in late Stage II or Stage III, however, occasionally a patient with an early Stage II lesion in this area will be seen In our series of cases, we have seen none with a Stage I lesion in these areas Stage II ventricular lesions require widefield laryngectomy Stage II false cord lesions, particularly if their growth is exophytic, will require widefield laryngectomy Stage II false cord lesions have potentially metastasized to the cervical lymph nodes when the patient is first examined Such individuals must undergo widefield laryngectomy and elective block dissection Further, metastases may occur on the contralateral side of the neck, and patients must be examined carefully and frequently following

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MODERN CRITERIA FOR DIAGNOSIS AND THERAPY OF MALIGNANT DISEASE IN THE UPPER RESPIRATORY TRACT*

JOHN J CONLEY, M D ,

New York, N Y

Melanoma of the head and neck presents us with significant clinical diagnostic, therapeutic and statistical data that warrant careful analysis Approximately 25 per cent of all the melanomas of the body occur in the head and neck area This of course, highlights the importance of diagnosing this condition accurately Fifty per cent of all the patients that we see, with melanomas in the head and neck give a history of having had a brown or black mole present all of their lives This means that you cannot disregard the lesion which has been present for a 20-, 30-, 40-year period Fifty per cent of the melanomas that we see give a history of repetitive trauma, not a single incidence of trauma, but repeated trauma, whether shaving, cleaning the teeth, combing the hair, at the collar line on the neck, in the mouth, on the lips, etc The same situation applies to fingers, feet, penis, anus, from the brassiere strap on the shoulder, from the belt buckle at the waist, etc

As far as the diagnosis is concerned, we feel that any change in color or clinical appearance, or any subjective change such as itching, stinging or burning, warrants careful observation of the pignmented lesion Certainly if the pigmented lesion begins to grow, if it gets blacker and larger, and if there is

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Pharyngeal and postcricoid lesions will be considered next Surgery is the treatment of choice for these A high percentage of patients with these lesions fall into Stage III when first examined Hence, most all of the cases with pyriform sinus lesions require some form of extensive pharyngeal and laryngeal surgery and block dissection of the neck Patients with early Stage II lesions of the lateral hypopharyngeal wall carry a good surgical prognosis, providing partial pharyngectomy and block dissection are carried out in continuity Patients with posterior hypopharyngeal lesions encroaching upon the upper esophagus require extensive surgery, both as to the local primary lesion and to the lymph bearing areas on both sides of the neck In addition, plastic repair of the pharyngeal and esophageal defects must be done The extent of such lesions usually precludes the saving of the larynx itself Since a high percentage of these cases have palpable cervical lymph nodes on initial examination, it must be decided by the surgeon whether the nodes are resectable before surgery is attempted

In our series of cases, we have had only two patients with primary subglottic squamous cell carcinoma One patient's lesion was classified late Stage II while the other's was classified as Stage III In neither patient was the disease arrested, in spite of extensive surgery Subglottic lesions metastasize early to the lymph channels in both sides of the neck and upper mediastinum As far as our limited experience is concerned, we believe that any known form of treatment for Stage II or Stage III subglottic squamous cell carcinoma is inadequate This is in contrast to those cordal cancers which have extended directly to the subglottic areas

V *Conclusions*

Many patients with carcinomas of the larynx and hypopharynx are still being examined initially in later stages of the disease, when only palliative therapy could be recommended In fact, approximately 20 per cent of our cases were classified as late Stage III and Stage IV The remaining 80 per cent of the cases underwent treatment directed at arresting the disease Surgical treatment was the treatment of choice in most instances the procedure. If it is reported as a malignant melanoma then I think you are obligated to go back and do a wider local resection, because no excisional biopsy technique is considered adequate treatment for malignant tumor.

So far as the treatment is concerned, irradiation is not effective. The salvage rate here approaches zero. Surgical excision is certainly the method of choice in all cases, when possible. The head and neck, fortunately, lend themselves better to technical excision than almost any other area of the body. We are not faced with the complex problem here of an individual with a melanoma on the sole of his foot or on his big toe, which poses the question of whether the entire leg should be amputated or disarticulated. Our areas are neat and tidy as far as regional activity is concerned. My own personal feeling is that if the melanoma is less than 2 cm. in size and there is no evidence of clinical metastasis, and if it is not necessary to operate in the neck to excise it, I no longer feel that any continuity resection is indicated. I do a wide resection of the primary lesion. If the melanoma is large—over 2 cm. in size—regardless of its position, but particularly if it is located on the neck, then an elective neck dissection is included in the absence of obvious metastatic disease.

If there is evidence of metastasis in the neck, the neck dissection is always included with the excision of the primary lesion. The salvage rate in our group of cases is not significantly higher where elective neck dissections have been done in the treatment of what we classify as situations with a high possibility of microscopic metastatic melanoma. I think the difference is only about 5 per cent and that is the reason I have retreated to a more reasonable position.

Unfortunately, melanoma can metastasize by any of three routes. Its most frequent mode of metastasis is hematogenous. When it does metastasize by the hematogenous route, the prognosis is hopeless. The next most common is in the regional lymphatic bed. Here the prognosis is between 25 and 30 per cent for the five year cure. I think that if we will appreciate that originally this disease was considered to be almost totally hopeless from a prognostic point of view, a 25 per cent cure is a reasonable figure; however, I would like to ulceration, it has to be considered as a melanoma Those which do not have such dynamic change in their biology of course are suspicious, but those that change in color and size, and which ulcerate, have to be considered as melanomas Here I think we must be careful not to be trapped by a condition which resembles this, called the pigmented basal cell cancer, also we have to be careful not to be trapped by the amelanotic melanoma which resembles the ulcerating squamous cell cancer but grows so rapidly without pigment mobilization that it may be confused with the squamous cell cancer

I think the other point in the differential diagnosis is what to do about the innocent or benign pigmented lesion, the neuronevus The most important factor here is separating the nevi which can undergo malignant deterioration from the ones which ordinarily do not This is an important clinical observation The nevi that are puckered like a wart, the nevi that have large hairy deposits in them—two or three big black hairs coming out of them—hardly ever undergo malignant deterioration, and I don't think that it is necessary to remove these prophylactically in anyone, unless it is desired for cosmetic purposes, however, the nevi that are flat, or smooth, either black, or dark brown, or blue-black, or buff colored, ordinarily can be troublemakers No one can tell with the naked eye the differentiation between an epidermal nevus, a dermal nevus, a subdermal nevus or a junctional nevus Actually, I think the feeling at the present time is that melanoma comes only from the junctional nevus, but those that we are interested in are the flat ones, not those that are puckered up like a wart and contain hair

As far as the biopsy is concerned, no incisional technique should be carried out In other words, you should not cut into this black ulcerating area to obtain tissue for biopsy This is a very strict rule If the lesion is ulcerating, you may apply fibrin foam or wash it and have a Papanicolaou examination done I believe the safest thing, however, is to do an excisional biopsy of the entire area In other words, you are at least a centimeter or two around the peripheral margin of the lesion you suspect, and this is sent *in toto,* en masse, to the laboratory If it is reported as a benign lesion, that is the end of

THE NOSE AND PARANASAL SINUSES *

HEINRICH KOBRAK M D,
Detroit, Mich,

and

G EDWARD TREMBLE, M D,
Montreal, Canada

About a year and a half ago, Dr Heinrich Kobrak approached me to see whether I would collaborate with him on a film He had in mind a movie of the nose and sinuses It was decided to show some of the anatomy and physiology of the nose and to conclude with a few clinical cases On his suggestion I was to supply the animation, pictures of ciliary movement and some of the cases Dr Kobrak was to take pictures of the skull to show the sinus openings and also some common conditions encountered It was thought that the film would be of use to senior students and internes A number of meetings were held to place the sequences in their proper order The last time Dr Kobrak was in Montreal was about the middle of September He was confident the film with the narration would be ready for the Academy meeting in Chicago in October Two days before the Chicago meeting, I received a letter from him asking me to meet him to go over the picture before it was shown at the general meeting

On arriving in Chicago, I learned the sad news that Dr Kobrak had suffered a fatal coronary attack a day or so before the meeting After searching his home and laboratory without avail, the film was finally found in the back of his car Whether he had just received it after being processed or whether he intended to drive to Chicago, I do not know As a result, it was up to me to carry the ball alone, so to speak

When I saw a preview of the film I was a bit disturbed Parts of it were overexposed, especially the microscopic slides

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state that five years in melanoma is not the answer to the problem because at the end of ten years the 25 to 30 per cent figure has dropped down to about 15. The third method of spread is in the subdermal lymphatics, and when melanoma behaves like this, it is, in my experience, practically uncontrollable.

I would make one statement about melanoma in children. As you know, the incidence of malignant tumors in children is very low. Shortly after birth it is about 20 per 100,000. Cancer in children is extremely rare. Melanoma does occur in children, but it does not have the same clinical significance as it has in adults. It does not metastasize as readily. It is usually handled by a local extirpative operation. Consequently, most of the nevi we see in children can be handled with impunity.

Melanoma of the oral cavity or any mucous membrane area has had almost a uniformly fatal ending.

ANNUAL OTOLARYNGOLOGIC ASSEMBLY UNIVERSITY OF ILLINOIS

The University of Illinois College of Medicine Department of Otolaryngology announces its Annual Otolaryngologic Assembly from September 29 through October 5, 1958. The Assembly will consist of an intensive series of lectures and panels concerning advancements in otolaryngology, and evening sessions devoted to surgical anatomy of the head and neck and histopathology of the ear, nose and throat. Interested physicians should write direct to the Department of Otolaryngology, 1853 West Polk Street, Chicago 12, Ill.

IRRIGATION OF THE MAXILLARY SINUS THROUGH THE MIDDLE MEATUS *†

MERVIN C MYERSON, M D ,

Beverly Hills, Calif

This paper is written primarily to stimulate interest in irrigation of the maxillary sinus through the middle meatus, preferably by way of its natural orifice There probably always will be some controversy regarding the relative advantage of irrigating this sinus by way of the middle or inferior meatus It will remain, however, for the individual rhinologist, by virtue of training, understanding, and experience, to decide the technique he wishes to follow in irrigating the maxillary sinus A few visits to the anatomy laboratory will convince the most skeptical that irrigation through the middle meatus can be performed in a high percentage of cases Although the more generally accepted method of irrigating the maxillary sinus is by way of the inferior meatus, using a needle or trocar, the number of otolaryngologists who are using the natural orifice and middle meatus is increasing Many rarely resort to puncture through the inferior meatus It has also been noted that it is easier to enter the maxillary sinus by way of the middle meatus in children than in adults

In order to appreciate the middle meatus approach one should have an understanding of the structures involved, and their relationships At about the tenth week of fetal life the mucous membrane of the primitive middle meatus of the nose begins to pouch laterally This evagination indicates the beginning of the maxillary sinus and is the location of the future maxillary ostium The maxillary ostium is situated in the posterior portion of the ethmoidal infundibulum where the posterior part of the bulla tapers away on the upper side, and the dorsal end of the uncinate process does the same on the

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I had suggested some lateral views of the normal nose, showing the sinus openings and the opening of the naso-lacrimal duct In other words, to my mind the picture could be improved and parts of it needed re-editing I have some film showing air currents through the nose and ciliary action in the presence of an acute cold, which I think would enhance its value, however, I just received the movie from New York about ten days ago, and I have not had time to add these sections I am only sorry that Dr Kobrak is not here when it is being shown in its original form

SOUTH CAROLINA SOCIETY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY

The next joint annual meeting of the North Carolina Eye, Ear, Nose, and Throat Society and the South Carolina Society of Ophthalmology and Otolaryngology will be held in Asheville, N C, on September 14-17, 1958, at Grove Park Inn An excellent program is in the making The following guest ophthalmologists will be present Dr James A C Wadsworth, New York, N Y, Dr Arthur Gerard DeVoe, New York, N Y, and Dr Frank B Costenbader, Washington, D C The following guest otolaryngologists will be present Dr F W Davidson, Danville, Pa, and Dr Tom Rambo, New York, N Y A third otolaryngologist will be announced in the near future A good attendance is anticipated

For further information write directly to Dr George Noel, c/o Cabarrus Bank Bldg, Kannapolis, N C, or Dr Roderick Macdonald, 330 East Main St, Rock Hill, S C

portion of the infundibulum immediately below the level of the orbital floor and, therefore, just below the lowermost portion of the lamina papyracea of the ethmoid bone (see Figs 1, 2) The orifice is usually so placed in the infundibulum beneath the middle turbinate as to be readily approached and entered in a large majority of cases At times it is buried deeply and may be inaccessible When the ostium is deeply placed, it is rarely hidden by the bulla, it is inaccessible in such cases because of the high obstructing uncinate process which governs the depth of the infundibulum Of importance also is the distance between the uncinate and bulla, the space commonly known as the hiatus semi-lunaris This space may be obliterated by contact of the bulla and uncinate, or it may be as wide as 3 mm When greatly narrowed it presents an obstacle to the ready passage of a canula

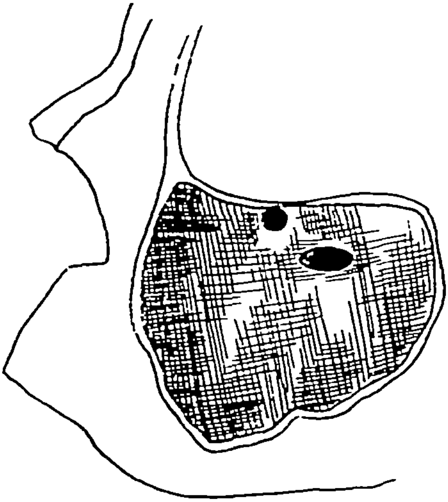

Fig 2 Semi-diagrammatic showing nasal wall of maxillary sinus and the usual location of the ostium an accessory orifice is located posteriorly and below

The size of the maxillary ostium varies from a diameter of 1 mm to a measurement of 17x11 mm Quite frequently the ostium occupies the entire infundibular region or most of it, lower side All of these structures, which vary in their size, contour and relationship, lie under cover of the middle turbinate The membranous portion of the middle meatus lies between the dorsal extremity of the uncinate process and the perpendicular plate of the palate bone, and between the dorsal extremity of the uncinate process and the ethmoidal bulla This has been called the undefended C-shaped region by

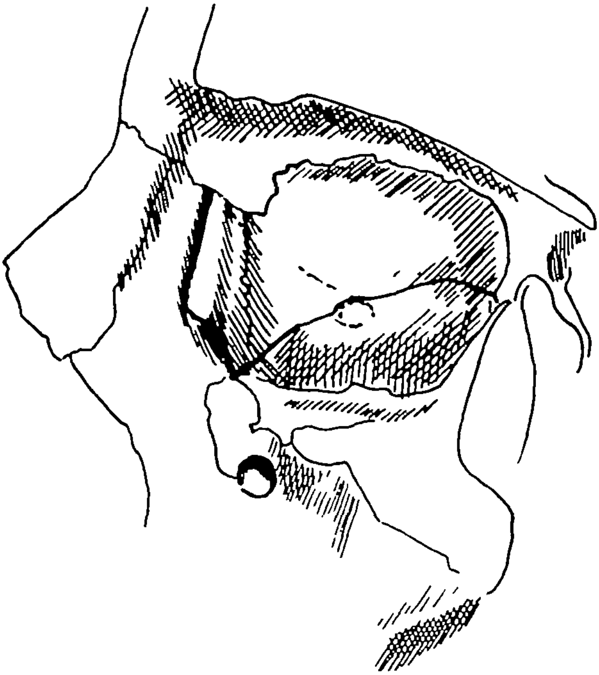

Fig 1 Semi-diagrammatic showing the relation of the infundibulum and maxillary ostium to the lamina papyracea orbital plate and surrounding structures

Schaeffer It is in this area that the accessory ostia are found

For success in the manipulation and introduction of a canula into the orifice of the maxillary sinus, it is important to have a knowledge of the maxillary opening and its accessory ostia, in addition to their relationship to the structures mentioned above

The orifice of the maxillary sinus is located in the posterior

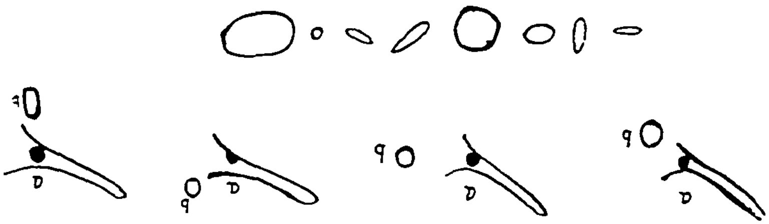

Fig 4 Semi-diagrammatic showing variety of sizes shapes and relative positions of the accessory ostium

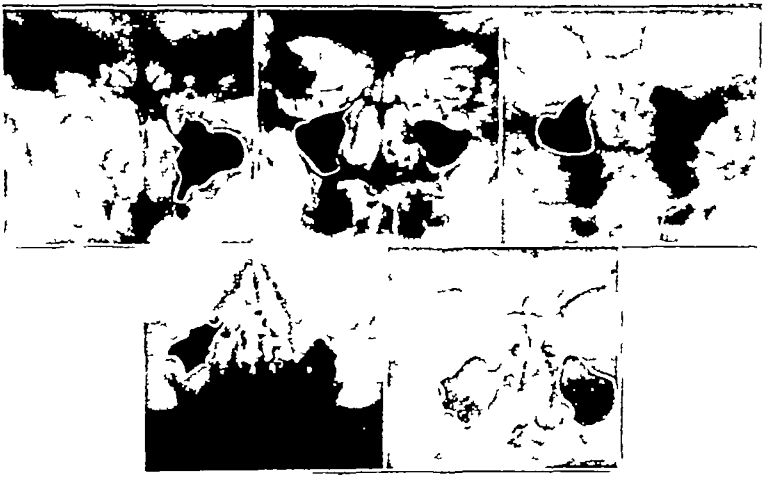

Fig 5 Roentgenographic studies made with iodized oil showing variety passageways into maxillary sinus

This paper is based upon a series of 500 consecutive patients in whom an attempt was made to irrigate the maxillary sinus through its natural orifice In those cases in which the ostium could not be entered, the membraneous portion of the middle meatus was deliberately punctured with the same blunt canula employed for entering the ostium The natural orifice was entered in 399, or 79 8 per cent, of this series of 500 cases, in 48, or 9 6 per cent, the membraneous portion was punctured with the same blunt-ended irrigation canula The total number irrigated through the middle meatus was 447, or 89 4 per cent, of the 500 subjects

In order to introduce a canula through the natural opening

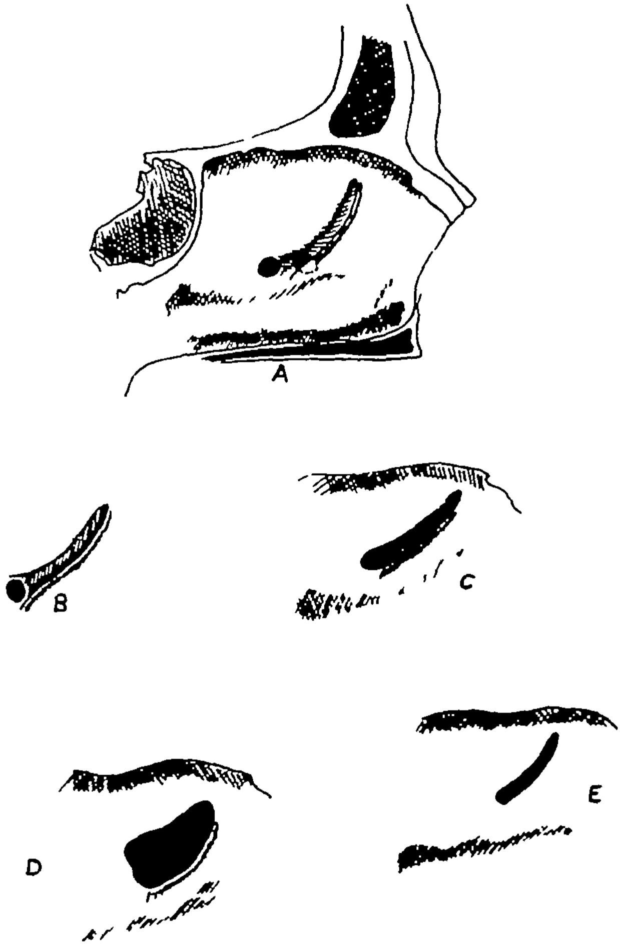

Fig 3 Semi-diagrammatic showing variety of maxillary ostia

so that a canula can be inserted with ease The size of the accessory orifice varies from a pinhead to 10 5x6 5 mm (see Figs 3, 4)

It is important to know that the position of the maxillary ostium may be vertical, horizontal or oblique When positioned horizontally or obliquely, it indicates the beginning of a canal or passage which terminates in a vertically placed orifice in the medial wall of the maxillary sinus (see Fig 5) These passageways have been stressed by Larroude, Simon, Van Alyea, and the author (see Fig 6) Simon claimed that a canal exists in 90 per cent or more of maxillary sinuses

With few exceptions, the tampon can be inserted into the region of the infundibulum, after three to five minutes it is removed and a fine cotton tipped applicator, saturated with the same cocaine solution, is placed in the same location The cotton-wound applicator can be bent so that its distal end can be properly placed When the middle meatus is anesthetized, an attempt is made to introduce the canula

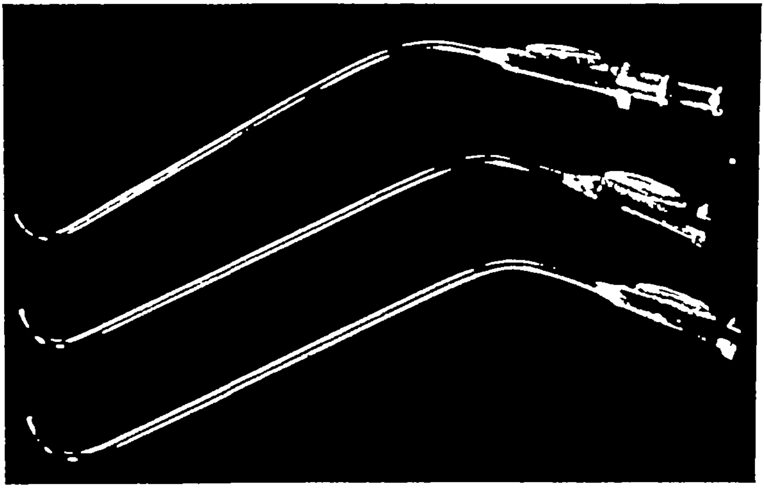

Fig 7 Author s canulae three sizes

The smallest possible canula should be used when the first attempt is made to enter the ostium The canula is introduced a few millimeters behind the anterior end of the middle turbinate with its distal end pointing upward When the middle meatus is reached, the tip of the instrument is directed laterally, if a vertically placed ostium exists, the canula will fall readily into it (see Fig 7) If the canula strikes the lateral wall it is withdrawn and introduced in an inverted position In this position the distal end will fall into a horizontally or obliquely placed orifice One can tell that the canula is in the ostium by the depth of penetration of the instrument and by the excursion of its distal end, which is controlled by the diameter of the orifice If an ostium cannot be found the membraneous portion of the middle meatus

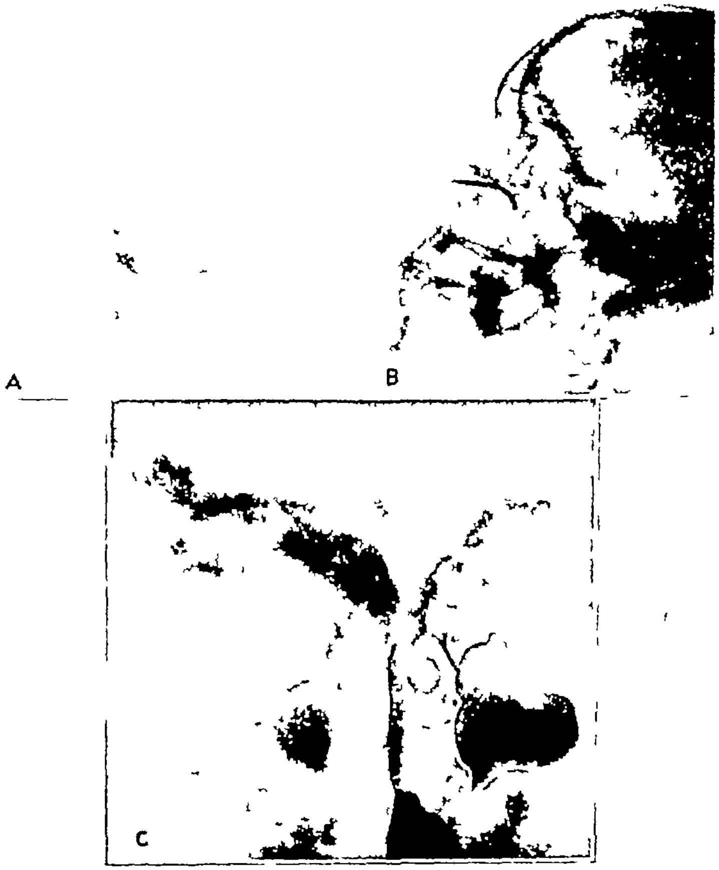

Fig 6 Roentgenographic studies showing (A and B) canula in oblique passageway (C) passageway after instillation of iodized oil

of the maxillary sinus, the middle meatus and the structures traversed by the instrument must be anesthetized To accomplish this a small flat tampon is inserted under the middle turbinate just beyond its anterior end It is advantageous to tie a piece of cotton thread to the tampon, the distal end of which is cut off at the nostril When anesthesia is complete, the tampon is removed by pulling on the thread This eliminates the necessity of using an instrument in the middle meatus, which sometimes bruises the tissues because of the narrowness of the passage or the depth of the position of the tampon, also, at times, the tampon is difficult to recover because of the extremely thick exudate which was expelled with difficulty, after inferior meatal puncture Acutely involved sinuses are never irrigated, but the exudate in cases of subacute or even chronic infections may be quite thick This, together with the presence of a small ostium, may cause slow emptying of the sinus cavity and, at times, some pain, but the irrigating fluid will usually be returned without incident That the ostium is rarely occluded has been proven by anatomic studies In a study of 600 lateral nasal walls, Zuckerkandl found the smallest ostium to be 3 mm in diameter, while the largest was 19x5 mm In 200 sections, Oppikofer found the smallest to be 2 mm in diameter and the largest 17x11 mm Schaeffer and the author found the smallest to be 1 mm in diameter

The number of otolaryngologists interested in natural orifice irrigation has increased with the years This is because they have found the procedure simpler and safer in a majority of cases Schaeffer states the reason as follows "One must bear in mind that instruments of precision, and a more highly refined technique, have come into being of late years, making successful treatment of an infected maxillary sinus by way of its natural aperture seemingly feasible in a relatively large percentage of cases" Many have stressed the advantages of irrigation through the natural orifice or through the membranous portion of the middle meatus

Those who object to irrigation through the natural opening claim there is difficulty in locating the ostium in a large percentage of cases They assert that the sinus cannot be properly irrigated when the return flow is partly blocked by the canula, and that instrumentation of the ostium injures and inflames its membranous lining If the anatomy is understood and the instruments properly manipulated, these objections are not valid

The objections to inferior meatal puncture have been known for a long time

The procedure is frequently painful, there is usually some bleeding, there is failure to penetrate with a needle or trocar because of thickened bone is perforated by the canula. Penetration through the membrane imparts a definite impulse which is readily recognized. In some cases there is a streak of blood, in most, there is none, while in others there may be no evidence of trauma. The condition of the membrane and its thickness, as well as the amount of trauma, influence the presence or absence of blood. When difficulty is encountered in the passage of the tube, one may bruise the middle meatal structures so that slight bleeding will occur for a few hours, or for as much as two or three days. The latter is exceptional and should not occur if the rhinologist is careful. When the canula is successfully introduced, there should be no injury to the tissues, nor should there be bleeding when the canula is withdrawn.

The presence of pus or mucopus in the returned irrigating fluid is evidence that the canula is in the antrum. The patient feels the fluid in his sinus, especially when the pressure of the fluid is increased. The sound heard when air is introduced into the antrum after irrigation, is distinctive.

In this series of 500 cases, the middle turbinate was impacted against the lateral wall so that the middle meatus could not be entered in 14 instances. When the space between the lateral aspect of the middle turbinate and the lateral nasal wall is so restricted, it is better to refrain from attempting to pass the canula, one should resort to puncture through the inferior meatus. At times a fine canula can be passed in an inverted position between the anterior end of the turbinate and the lateral wall, instead of beneath the anterior end of the middle turbinate, as is usually done. In five cases the middle turbinate could not be visualized because of a badly deviated, or convex septum.

It was found that patients who had nasal polyps protruding from the middle meatus presented an enlarged natural opening, so that a canula could be passed with relative ease. One is also impressed with the large number of orifices of increased diameter among the cases of chronic suppuration of the maxillary sinus.

Occlusion of the ostium during irrigation is more theoretical than real. Occlusion of the ostium occurred once in this series

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The needle or trocar can fall into or beneath thick necrotic or polypoid membrane and cause air embolism or infiltration and emphysema of the cheek and eyelids

Phlegmon of the soft parts of the face can occur, fluid can be injected into the pterygomaxillary fossa

Air embolism is a well-established accident of inferior meatal puncture Many deaths have been recorded

An attempt was made to enter the natural opening of the maxillary sinus in 500 consecutive cases The ostium was successfully entered in 399, or 79 8 per cent, in 48, or 9 6 per cent, the membranous portion of the middle meatus was punctured with the same canula used for entering the ostium A total of 477, or 89 4 per cent, therefore, were successfully treated through the middle meatal approach

Irrigation of the maxillary sinus through the middle meatus, either by way of the natural opening or by puncture of the membranous portion of the middle meatus, is a safe and simple procedure On the basis of my experience it should be recommended as the method of choice

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COMMENTS ON A FOURTH YEAR OF TRAINING FOR CERTIFICATION IN OTOLARYNGOLOGY

GORDON D. HOOPLE, M.D.,
Syracuse, N.Y.

BACKGROUND

Just ten years ago, the American Board of Otolaryngology, following a review of the status of otolaryngology during and following World War II, decided the training of otolaryngologists needed strengthening. It ruled that all applicants for certification by the Board would be required to have three years of residency in otolaryngology if they began their training after July 1, 1950. At the time, there were not a few who expressed concern about this increase in the length of training. Today, however, there is no thought of a return to the former two years. There is universal acknowledgment that this move has been productive of great benefits to otolaryngology.

Ten years have passed since the announcement of this ruling. During these years, a more systematic and thorough system of appraising the residencies in otolaryngology in this country has been established. The appraisal body is known as the Residency Review Committee for Otolaryngology. It has succeeded the former Review Committee of the American Board, which, when it was in existence, passed judgment on residency training programs independent of the inspections of the American Medical Association and the American College of Surgeons. When this system was in vogue, there was

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confusion and inefficiency, and the settlement of any differences between official inspections of the three bodies (and there were some) often took one to two years to iron out. The present Residency Review Committee, then, has three cooperative sponsoring organizations: the American Medical Association, the American College of Surgeons, and the American Board. There is equal representation on the committee, four otolaryngologists from each of the three parent bodies. Each of the parent bodies has agreed to accept the judgment of these twelve men on any given residency. This means that approval or disapproval of a residency program, once it has been decided by the Residency Review Committee, has the simultaneous sanction of the American Medical Association, the American College of Surgeons, and the American Board. Order has come out of the confusion. The Residency Review Committee is more efficient, and its judgments are much more accurate and reliable. These judgments are the result of studied and often lengthy deliberations of twelve serious and dedicated men.

Over the past five years, the Residency Review Committee has processed an intense amount of data on otolaryngologic residency programs in the United States. The Committee meets twice a year, giving two days to each session. No other matters are considered save material pertaining to residency training programs in otolaryngolgy.

Good thinking and sound judgment have been used. As a result of these five years of deliberation, during which time the approval of more than a few residencies has been withdrawn (including, unfortunately, some university programs), a feeling has arisen amongst the members of this Committee that the 1948 action of the American Board of Otolaryngology, *good as it was, was not enough. It has been felt that additional* requirements were necessary to bolster the training of otolaryngologists. This feeling has not been crystallized by the Residency Review Committee, for this is not its function. (Approximately 50 per cent of the membership of the Residency Review Committee is made up of otolaryngologists who are not directors of the American Board of Otolaryngology.) A formalization into a regulation can properly come only from the American Board of Otolaryngology Such action has been taken by the Board, but it should be noted that this action did not arise out of thin air, nor was it the result of pressures by individuals or groups outside of otolaryngology It was as a result of the combined opinions of the men who are in the best position to know the strengths and the weaknesses of Otolaryngologic Residencies throughout the country, *e g* , the members of the Residency Review Committee, and the men who see these same strengths and weaknesses manifest in the examination of candidates, *e g* the members of the Board

THE ACTION TAKEN

At a meeting of the American Board of Otolaryngology held in October, 1957, in Chicago, the Board voted to add an additional year of training to the three-year training period in otolaryngology The Board made public announcement that the additional year was to be devoted to straight surgical training

At a subsequent meeting held in San Francisco in May 1958, the previous action was modified At this meeting the American Board of Otolaryngology reaffirmed the requirement of a four-year approved residency training program, at least three years of which shall be in otolaryngology The Board modified the requirement of one year of general surgery The additional year of training may be devoted to otolaryngology or to other fields, such as surgery, medicine, pathology, basic sciences, or research

SOME SPECIFIC REASONS FOR THE ACTION TAKEN

1 During the early part of this Century, some of the rightful functions of otolaryngology were lost by default Occupied with infections of the sinuses and ears, the otolaryngologists of the country neglected to keep pace with advances made in the field of nasal and facial fractures, nasal deformities, and regional plastic surgery, also, with a few notable exceptions, the major surgery for malignancies of the sinuses, the larynx, tongue and in the neck, was not included in the training of otolaryngologists All of this requires excellent surgical technique and sound surgical judgment, in addition to a knowledge of the physiology and function of the structures involved and an understanding of the general nutritional problems encountered

2 In the past five years too many of the residency programs in otolaryngology have graduated men whose surgical record was deficient (It is a requirement of the Residency Review Committee that a program under review must submit to the committee a list of the operations performed in that residency by the staff and by the residents) The paucity of procedures in several programs has been notable In a majority of such instances, otolaryngology has been but a division of the Department of Surgery, and these procedures were not available to the residents in otolaryngology About 60 per cent of all the residency programs in otolaryngology are under control of the Department of Surgery in their institutions In a goodly proportion of these, budgets are insufficient, an adequate number of hospital beds is not available, and little or no research is in progress

3 The tempo of residency training has slowed Many residents are married, and the end of a day's work is often 5 o'clock, and not 11 or 12 o'clock at night, as it was in former days There is now more to teach and less time in which to do it

4 During the past ten years, there has been an increasing number of so-called oncologic surgeons trained These surgeons are supposedly trained to handle, surgically, malignancies in any location in the body In the knowledge of yesteryear, this new specialist might be a boon to medicine, but in the light of modern medicine, with the necessity for knowing much about function, as well as anatomy, and with the availability of diagnostic methods and armamentaria which are best employed by specialists in their use, oncologic examination, surgery and follow-up are not equal to that which can be performed by well-trained specialists in local areas Otolaryngologic residents must have adequate training in this field

5 Another important reason is the action taken by the

National Institute of Health A number of years ago this body felt that ophthalmology needed bolstering and spent some of its energies and monies for better training in ophthalmology, and the teaching of ophthalmology has improved The National Institute of Health now feels that the teaching of otolaryngology needs strengthening, in fact, it is a specialty needing help more than most others It is planning to spend thousands of dollars over the next ten to twenty years for the training of teachers and research men in the field of otolaryngology This is the opinion of a group outside of otolaryngology This is significant

6 The most important reason for an additional year of training in otolaryngology is the recent broadening of the field Better training is needed so that future trainees will have a working knowledge of the many facets of modern otolaryngology The scope of otolaryngologic surgery now includes procedures which are as complicated and demanding as any in the field of surgical endeavor (Rehabilitation service for some of these patients demands a thorough knowledge of many techniques), but there is also in this broad field the most delicate surgery of all—microscopic surgery of the ear A very large portion of all allergy falls within the scope of otolaryngology A modern otolaryngologist must know much about audiology He cannot practice intelligently without this knowledge, yet, this science itself has grown to the point where studies at the doctorate level are required to encompass its broad reaches A practical working knowledge of endocrinology is needed by the modern otolaryngologic specialist Research in all these areas is expanding significantly From what was thought to be a narrowing specialty in the mid-forties, otolaryngology has grown to become one of the broadest and most inclusive specialties of all This is demonstrated when medical students are adequately exposed to it Their response is usually one of amazement at the scope of the specialty and the opinion that they develop is at least one of respect, and often this is followed by an active interest

HOW WILL IT WORK?

The May, 1958, action of the Board of Otolaryngology purposely made the extra year of training flexible Surgically oriented residents may spend one year of the four in straight surgery and yet receive credit for the year Likewise, medically oriented residents may spend a year in medicine

It may be asked, "Why should any surgery be included in the training of one who wishes to confine his practice to the medical aspects of otolaryngology?" The answer to this is that the very best internists are those who attend the surgery performed on their patients and know what is done, so they can intelligently treat them in the future Medical otolaryngologists (they exist, and the good ones should be respected and admired) will be better specialists if they have had some surgical experience

Various other combinations are approved It is conceivable, for instance, that a resident may take two years of ear, nose and throat training, spend a year in otolaryngologic research, and then take a fourth year in otolaryngology He should make a most valuable senior resident

If the choice is a year of surgery, this year should be oriented to the needs of the otolaryngologic resident During the *year of general surgery, the individual should receive training* in patient care, which would include study of fluid and electrolyte balance, wound repair, shock, flaps, grafts, and dietary deficiencies of tube fed patients Operating room experience in the areas of interest to the otolaryngologist, namely, neck surgery, chest surgery, neurological surgery, etc, should be included In general, it would appear advisable to place this year of surgery between the first and third years of the otolaryngologic residency, which will be after the resident has some knowledge of what should be gleaned from this extra year This surgical experience can be obtained in the same hospital in which the sponsoring otolaryngological department functions or in a neighboring institution if it appears that better values can be realized It is only necessary that a qualified surgeon be in charge of the approved surgical service which is to train the otolaryngologic resident

Probably, many of the otolaryngologic residencies of the country will make this program a straight four years in otolaryngology. Where the facilities of a department are such that the material, the teachers, and the armamentaria are available and of good standing, this will be the sensible arrangement.

A LOOK TO THE FUTURE

The American Board of Otolaryngology has realized it must make moves which will strengthen the teaching of otolaryngology. With a long look into the future it has made the present ruling, *i. e.*, an extra year of training. Otolaryngology has expanded. There is no denying this. Almost surely, it will expand further. (The bio-acoustics of space travel, for instance.) The extra year of training has been added to prepare residents properly for the very broad field now emerging. In the future, not everyone will practice the entire field, but everyone should have training in all ramifications, so proper diagnoses, referrals, and follow-ups will be made. Only complete training will accomplish this.

Apparently, there is a need for more otolaryngologists in the United States today. One school of thought may argue for lower standards, so more practitioners will be produced. The time to increase standards is when there is a need for additional workers and when expansions in scope demand additional training. This is the situation today and is one of the reasons why the change has been made. It is believed that the response of future medical students will be adequate and rewarding.

This proposed year of additional training has seemed startling to some and to others, unnecessary. This is probably so, because not everyone is familiar with all this background material which has been available to the members of the Board. What everyone should remember is that this move has been made in view of the facts above outlined. It has been done in order to strengthen otolaryngologists and thus, to strengthen otolaryngology itself; all other reasons are subservient to this.

POSTMORTEM CHANGES AND ARTIFACTS IN HUMAN TEMPORAL BONES [*][†]

CESAR FERNÁNDEZ, M D ,

Chicago, Ill

I INTRODUCTION

The recognition of autolytic changes in human specimens is particularly important because, as a rule, the temporal bones are removed and fixed some hours after death, when autolysis is well under way This process may have developed to the point where pathologic change is masked or its recognition impeded, furthermore, autolysis and pathologic change often are intermingled with artifacts, so that a differentiation between one and the others remains uncertain To minimize these complications, the technique of injecting a fixative into the middle ear soon after death was developed The rationale was that the round window and probably the oval window are the main pathways of the fixative Then, if this was injected into the middle ear soon after death there was a good chance to eliminate or minimize the autolytic process Another procedure based on the same reasoning was removal of stapes before immersion

The purpose of the investigation to be described here was to compare the results in human temporal bones treated by three procedures—removal of stapes before immersion, immersion, and early fixation by injecting formalin into the middle ear soon after death The investigation was concerned with the preservation of the inner ear structures, study of patterns of postmortem changes and artifacts in human temporal bones, and comparison with those observed in guinea pigs [1]

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[*] This investigation was supported in part by funds provided under Contract No B-1330 with U S Public Health Service by Contract AF 41 (657)143 with the School of Aviation Medicine USAF Randolph Field Air Force Base Texas and by a grant from the Central Bureau of Research of the American Otological Society

[†] From the Division of Otolaryngology of The University of Chicago

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II MATERIAL

The study included 53 human temporal bones taken from 28 cadavers which were kept under refrigeration (between -1 1° and 4 4° C) until autopsy The technique for removing human temporal bones as described elsewhere[2] was used

Removal of the stapes before immersion in fixative was done in two specimens Helly's fluid was used as the fixative and nitric acid as the decalcifier The immersion procedure, which consisted of removal of temporal bones and then immersion in fixative, was employed in 25 specimens In this group Helly's fluid, Zenker's solution, or Heidenhain-Susa were used as fixatives, and nitric acid, trichloroacetic acid, or formic acid plus sodium formate, as decalcifiers The technique for injecting fixative into the middle ear, as developed in the Department of Otolaryngology of the University of Chicago Clinics, was as follows One injection (10 cc) of 10 or 20 per cent formalin through the tympanic membrane, as soon as possible after death, removal of temporal bones at autopsy and immersion in fixative This group included 26 specimens Fixatives and decalcifiers as in immersion procedure were employed

The temporal bones were sectioned at 20 microns, and one of every ten or twenty sections stained as described elsewhere[3] with hematoxylin-eosin or Mallory's azan The preparations were studied under regular light microscopy

III DEFINITIONS

There are two types of artifact which should be differentiated one is primary, and is the result of interaction between reagents and membranes, fluids and cell constituents In the guinea pig this result was called the normal microscopic cytoarchitecture of the inner ear[1] when fixation by intravital perfusion of Heidenhain-Susa and staining with hematoxylin-eosin were used

The normal microscopic cytoarchitecture of the human inner ear must be defined in terms of the best result obtained by any procedure Examination of these specimens showed a homogeneous rather than a granular-like cytoplasm, in almost all cell populations of non-nervous tissue Undoubtedly this, together with some precipitates and globular formation, are signs of postmortem changes Golgi's apparatus, centriole and mitochondria were absent, as they were in animal specimens In the nucleus, the granular-like formation was also absent, and the karyosomes barely differentiated The plasmosome stained more prominently than any other cell constituent The cell bodies of Corti's ganglion presented swelling and homogenization, while Scarpa's ganglion was better preserved Size, shape and position of cells and membranes were, in general, comparable to those found in animals Any change

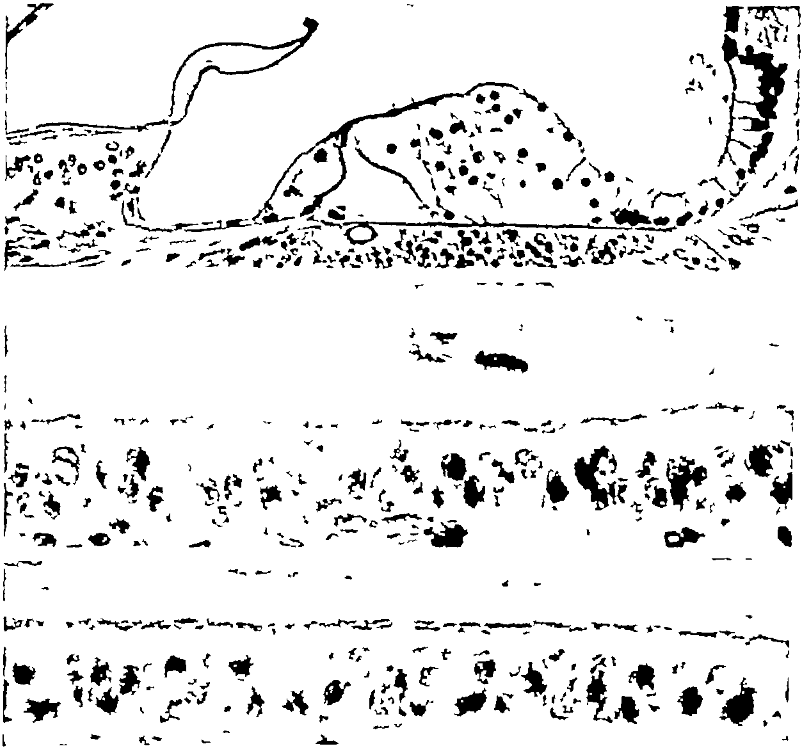

Fig 1 Good preservation of structures with minimum postmortem changes From top to bottom Organ of Corti (H-E X255) macula saccularis (H-E X625) and macula utricularis (H-E X625) Fine details of cell constituents can be identified

in this picture, other than pathologic or autolytic processes, was called secondary artifact For convenience, the term artifact has been used here to mean, unless otherwise specified, the secondary artifact

In the series of 53 human temporal bones a wide variation in degree of preservation was found The results were defined in terms of the efficiency of the methods in preserving the inner ear structures from postmortem changes and artifacts Using this criterion, the specimens were divided into four categories *1* Good, postmortem changes and artifacts were at a minimum These specimens were considered to demonstrate the normal microscopic cytoarchitecture of the inner ear and they were the ones to which all others were compared In Figs 1 and 2 the best samples of structures ideally preserved are presented The degree of preservation for individual specimens, in general varied from one structure

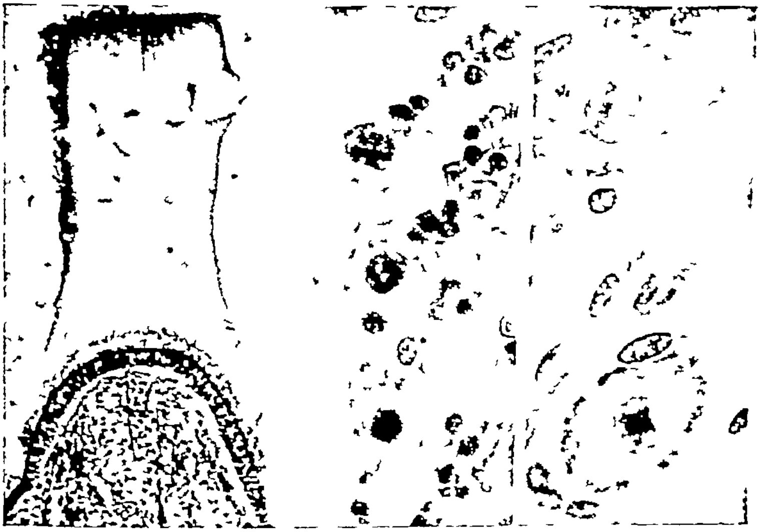

Fig 2 Good preservation of structures Left crista and cupula of a semicircular canal (H-E X105) in which there is some precipitate around the cupula and also over the surface of sensory epithelium Center cell bodies of Corti's ganglion (H-E X700) showing edema and hemogenization but in general nuclei are well preserved Right cell bodies of Scarpa's ganglion (H-E X700) in which the fine details of cell constituents are preserved

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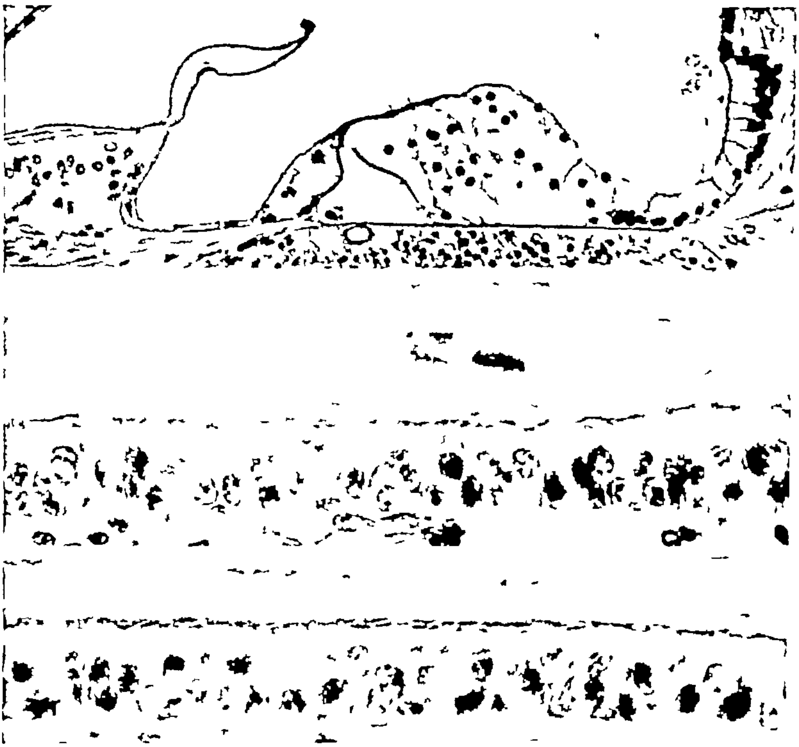

Fig. 1. Good preservation of structures with minimum postmortem changes. From top to bottom Organ of Corti (H-E ×255) macula saccularis (H-E ×625) and macula utricularis (H-E ×625). Fine details of cell constituents can be identified.

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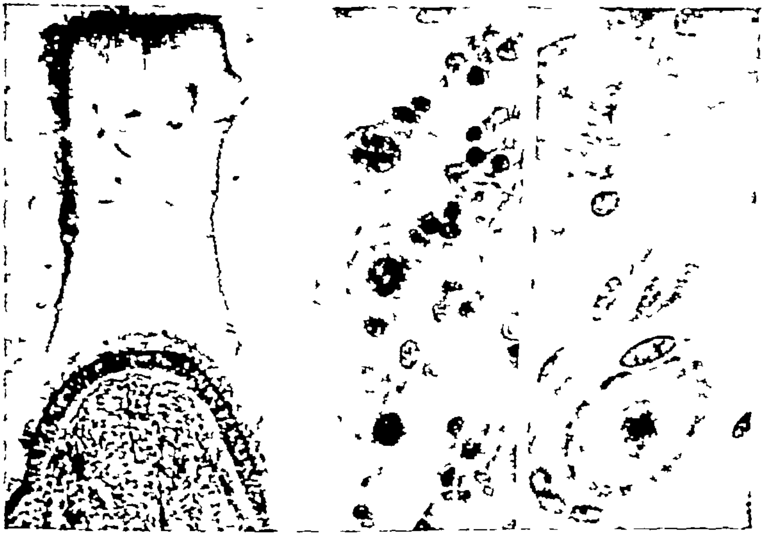

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to another, the variation consisted mostly in more or less advanced postmortem changes *2* Fair, still more advanced postmortem changes and/or artifacts Precipitates and distortion of cells by swelling and homogenization were the most prominent features, however, cell membranes, nucleus and general cytoarchitecture were preserved, and consequently the specimens were useful for histologic studies *3* Poor, the cells were so distorted by postmortem changes and artifacts that usefulness of these specimens for histologic studies was questionable The distortion affected the organ of Corti more than structures of vestibular receptors Finally *4* unsatisfactory, useless for histologic studies of fine details

It must be clearly understood that this grouping of results into four categories was based only on the efficiency of the procedure for preserving the inner ear Any specimen, no matter how distorted it is by advanced autolytic process or artifacts, can be used for histologic studies of gross pathologic changes In cases of tumor, hemorrhage, atrophy of cochlear and vestibular nerve, infection, and other conditions the lesion can be identified, even though the fine details may be completely lost In other cases, such as acoustic trauma, intoxication and degenerative processes, the preservation of fine details is critical Our grouping was made with this latter type of pathologic change in mind

For convenience, the following definitions are given Injection time was defined as the time between death and injection of formalin into the middle ear Pre-refrigeration time meant the time between death and transfer of cadaver to the Pathology Department, as was found in the medical record We were informed that all cadavers are put in the refrigerator as soon as received In a few cases the pre-refrigeration time was questionable because it was too short Refrigeration was defined as the time the cadaver remained in the refrigerator, and immersion time as the time interval between death and immersion of the specimen in fixative

IV PRESERVATION AFTER REMOVING THE STAPES

In one cadaver the pre-refrigeration time, refrigeration and immersion time were three, eight and 13 hours respectively The stapes was removed in both ears, just before immersion The preservation of both temporal bones was classified as fair The Organ of Corti presented edema and homogenization of cells, precipitates, and globular formation In one specimen Reissner's membrane collapsed over the Organ of Corti without compressing it, in the other, Reissner's membrane was straight The sensory epithelium of vestibular receptors showed the same pattern of postmortem changes and similarly, the vestibular walls collapsed in one specimen without compressing the receptors In Fig 3 the Organ of Corti and a region of macula saccularis are illustrated The ganglion of Corti showed swelling and homogenization of cell bodies but no pyknosis In Scarpa's ganglion the granular-

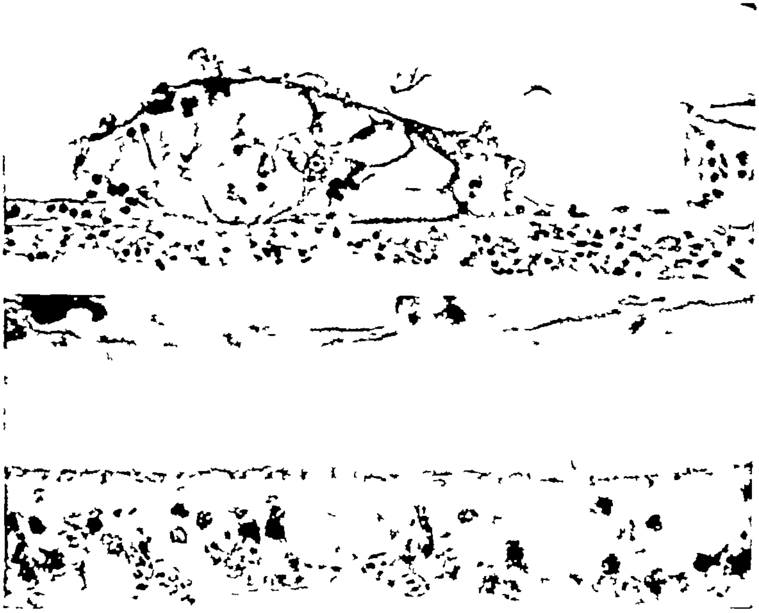


Fig 3 Fair results obtained by removing the stapes before immersion of the specimen in fixative H H 58 years cancer of the lung The Organ of Corti (H-E X255) presents edema of cells precipitates and globules but cells can still be identified The macula saccularis (H-E X625) shows edema of some sensory cells precipitates and globules between otoconia and sensory epithelium

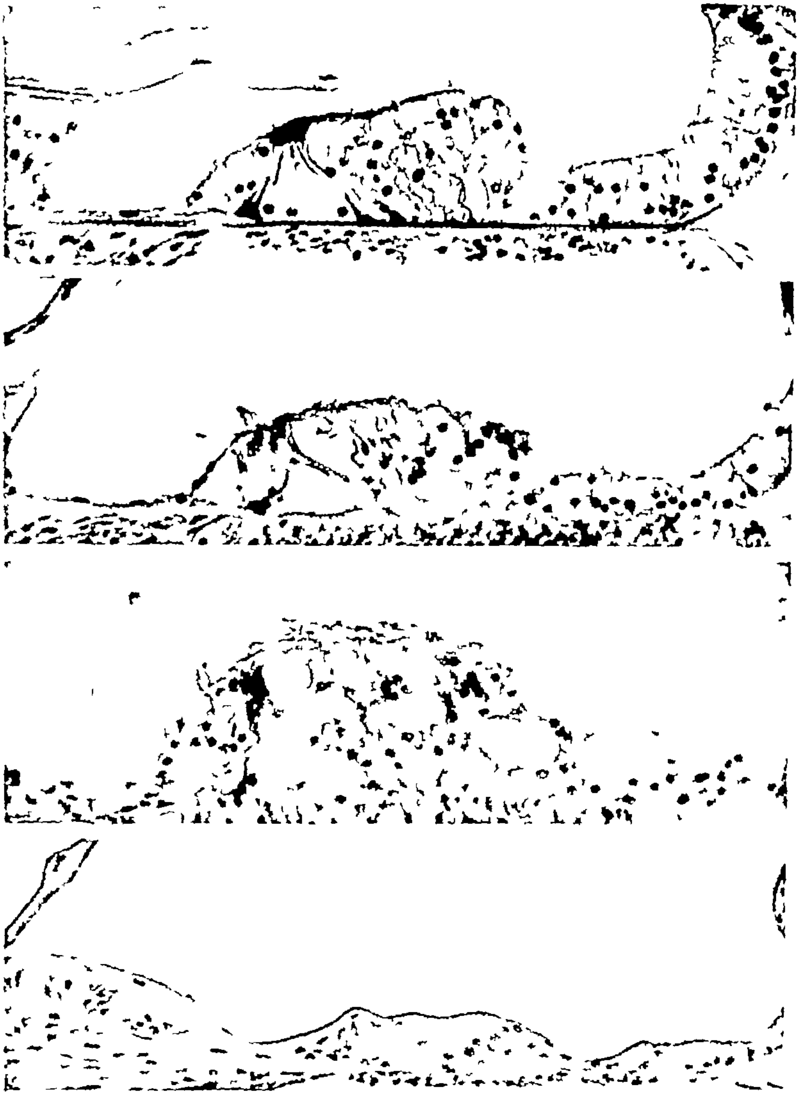


Fig 4 Type of results in the Organ of Corti obtained with the immersion procedure From top to bottom good (Mallory's azan stain ×255) fair (H-E ×255) poor (Mallory's azan stain ×255) unsatisfactory (H-E ×255) Fair and poor results were caused mainly by postmortem changes while the unsatisfactory was due to compression of the Organ of Corti

like cytoplasm and constitutents of the nucleus were differentiated

The procedure gave results which were no better than those of other methods It had the disadvantage that structures of middle ear may be largely destroyed during removal of stapes, and consequently, the procedure is not suitable for these particular studies Investigations with guinea pigs[1] showed that preservation of cochlear structures was as good by immersion procedure alone as it was by removal of the stapes With the latter, vestibular structures were better preserved, but there was a tendency to produce collapse of the membranous labyrinthine walls

Recapitulating, the investigation in animals and the study of two human temporal bones indicates that the removal of the stapes had more disadvantages than simple immersion

V PRESERVATION AFTER IMMERSION PROCEDURE

The histologic picture of the cochlea, vestibule and nervous elements will be described and discussed separately

Cochlear Receptors The results were as follows Good in seven, fair in two, poor in five, and unsatisfactory in eleven The four types of preservation are illustrated in Fig 4 Fair and poor results were brought about mainly by postmortem changes, while preparations were judged to be unsatisfactory primarily because of artifacts

Different degrees of swelling and homogenization with or without pyknosis characterized the picture of postmortem changes In poor results, large and numerous space formations in the Organ of Corti were seen, but we could not decide whether this represented edema of cells or intercellular spaces Precipitates and globular formation over surfaces, in Organ of Corti and/or cochlear spaces were consistently observed Comparison of these findings with those of experimental animals showed that the characteristic sequence of autolysis as a function of time was not seen in human as clearly as in animal specimens Fig 5 shows that the progress of autolysis was delayed in human preparations The immersion time in

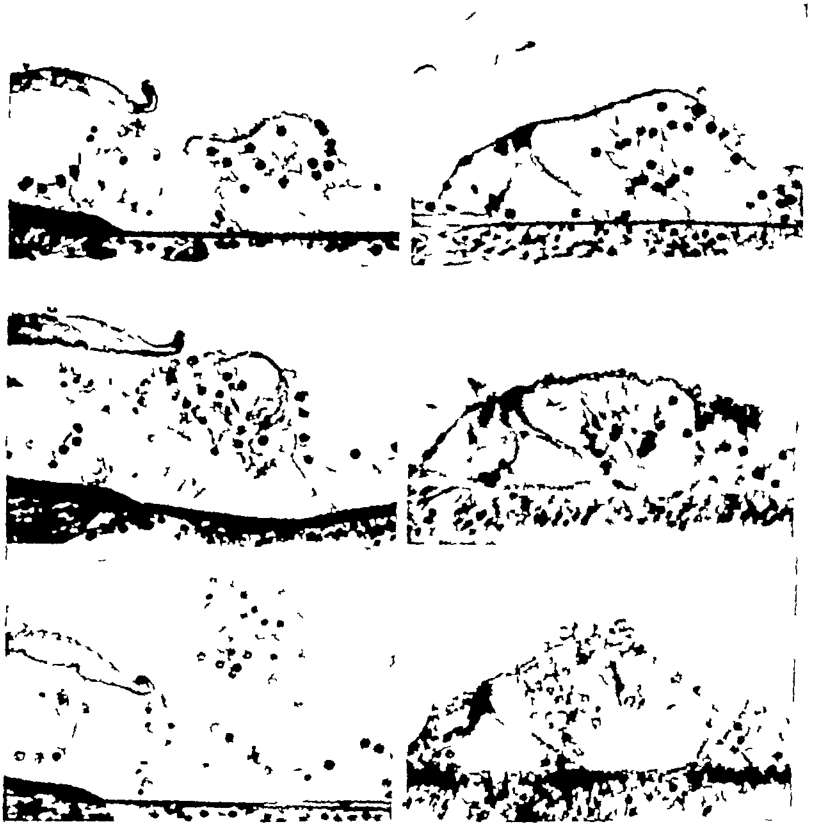


Fig 5 Comparison of autolytic changes in the Organ of Corti as function of time in guinea pig and human specimens Immersion procedure was used in all these cases The photomicrographs in the left column belong to guinea pig specimens immersed in fixative 6 10 and 20 hours after death (from top to bottom) In the right column are the corresponding samples of human specimens immersed 6 11 and 18 hours after death The figure illustrates that the autolytic process was faster in animal than human specimens The difference may be due primarily to refrigeration of human cadavers Mallory s azan stain was used in these sections except the middle one in the right column which was stained with H-E All photomicrographs X255

the 25 specimens varied between four and 20 hours In general, the degree of postmortem change increased as this time was prolonged Occasionally a specimen fixed a few hours after death presented more advanced autolysis than another which had been put into fixative many hours later Disintegration of cochlear structures, as seen in later stages of the autolytic process in animals, was found only in the stria vascularis of one specimen This was a child of 15 months

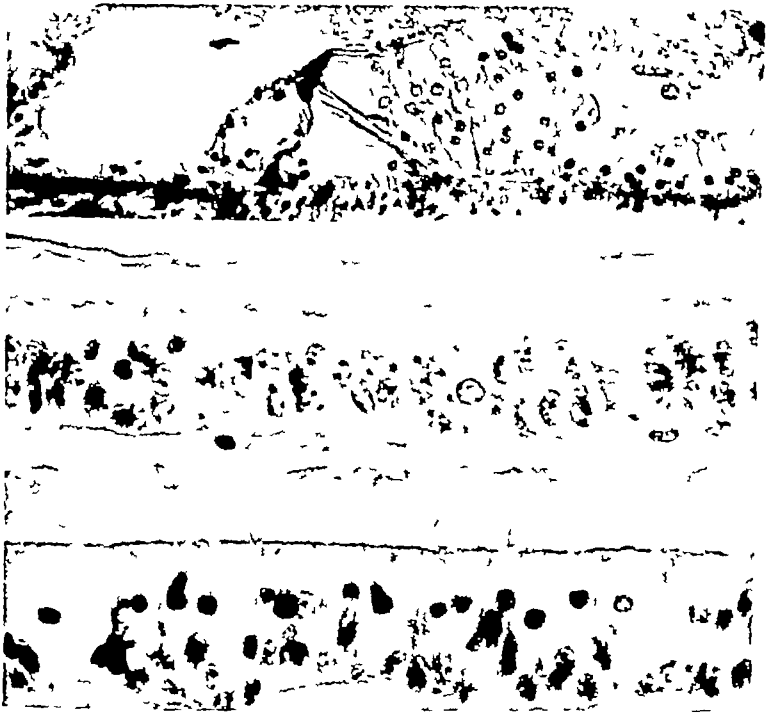
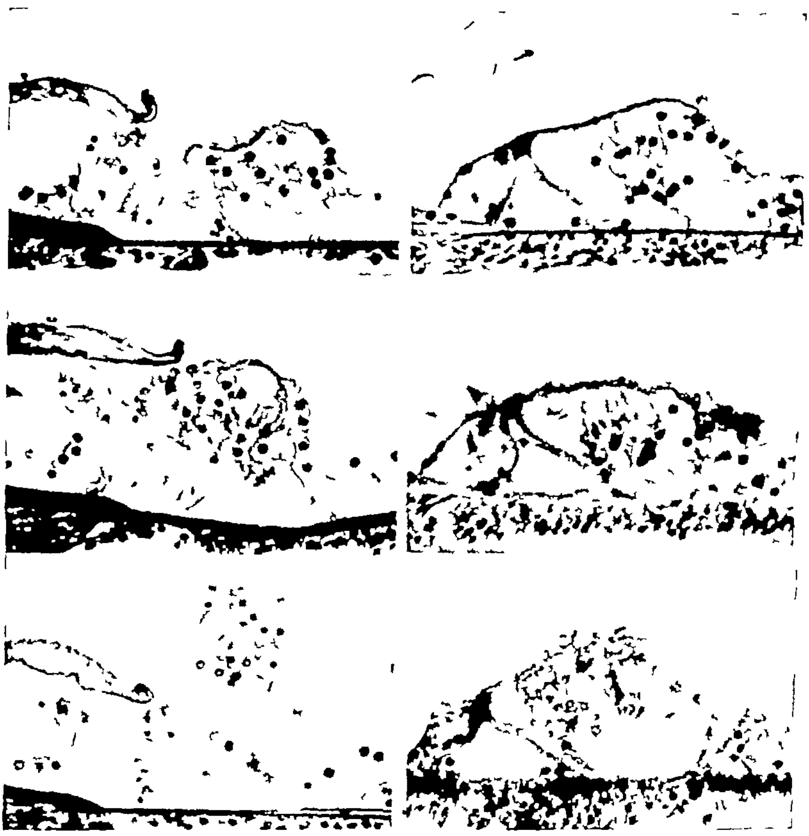


Fig 6 Good preservation of structures in a specimen in which the cochlea was broken during dissection of temporal bones By mistake the specimen remained in decalcifier for about four months From top to bottom Organ of Corti (Mallory's azan stain ×255) which presents precipitates over the surface macula saccularis (H-E ×625) where no postmortem changes are detectable and macula utricularis (H-E ×625) in which some sensory cells present edema and pyknosis The good preservation of structures might be attributed to facilitation of penetration of fixative through the broken cochlea however in the opposite ear where the cochlea was not broken the same results were obtained Refrigeration of cadaver seems to be the main factor in preserving this specimen from progress of autolysis

with a fracture of the base of the skull Immersion time of these temporal bones was 12 hours Disintegration of the stria vascularis was similar to that found in animal specimens immersed ten hours after death

The reason for the difference in the trend of postmortem changes in human and animal preparations was not clear We did not find evidence which could be related to terminal temperature of the patient, fixatives, decalcifiers or other steps in the histologic technique Difference in species and



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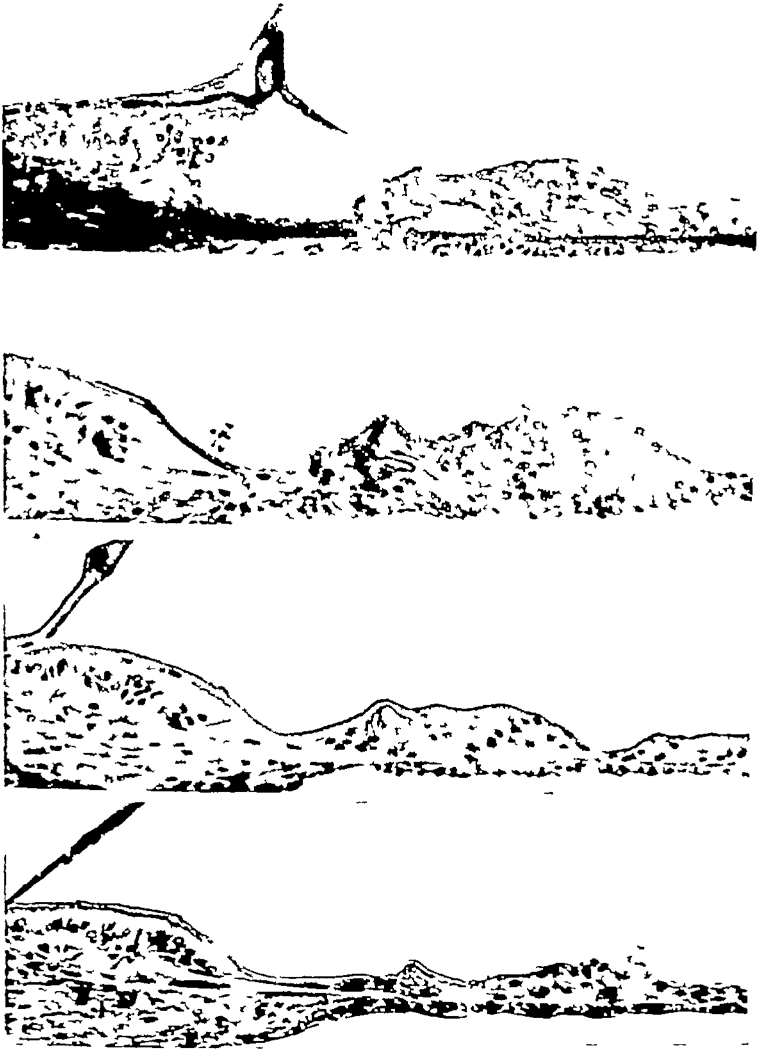

Fig 7 Several degrees of compression of the Organ of Corti from slight distortion to complete flattening In all cases the tectorial membrane is reduced to a thin lamina which generally appears collapsed over internal sulcus cells and Organ of Corti The degree of compression is reflected also in the limbus which in extreme cases may be flattened over the internal sulcus as the photomicrograph at the bottom of the figure illustrates In all cases the mesothelial cells appear agglutinated to the basilar membrane The section at the bottom of figure was stained with H-E the others with Mallory s azan stain All photomicrographs X255

conservation of cadavers in refrigeration until autopsy seem to be the most probable factors. Although refrigeration delays the autolytic process, the pre-refrigeration time must be considered, because the cadavers were exposed to room temperature (about 25.5° C) and consequently autolysis progressed steadily. This time varied from 30 to 170 minutes. As expected, the best results were found in specimens with the shortest pre-refrigeration time, but even among these there were unsatisfactory preparations. An example which may illustrate the importance of early refrigeration is given in Fig. 6. This was removed from a cadaver refrigerated 30 minutes after death and the temporal bones immersed in fixative 14 hours later. The photomicrograph shown in Fig. 6 is of the ear in which the cochlea was broken during dissection. This temporal bone was misplaced during decalcification, where it remained for about four months. The good results might have been attributed to facilitation in penetration of fixative, however, the opposite ear, where the cochlea was not broken, and the temporal bone not misplaced, showed as good results. This suggested that early refrigeration of cadavers is very likely of considerable importance in preventing or impeding postmortem change in temporal bones.

Detachment of tectorial membrane from the Organ of Corti was a consistent finding, but the membrane did not shrink as much as in experimental animals. This may be a matter of difference in size of this structure in the two specimens. Detachment of this membrane from the limbus was also observed in cases with advanced postmortem changes. The position of Reissner's membrane varied from straight to complete collapse (see Table I). Artifacts, such as detachment of Hensen's from Deiter's cells, space formation in internal and/or external sulcus cells, were almost absent.

Compression of the Organ of Corti accounted for almost all the unsatisfactory results. This phenomenon was characterized by collapse of the structures to such an extent that cells frequently could not be identified. The cytoplasm was dense, the nuclei were pyknotic and cell borders diffuse. The pillars of Corti and cuticular lamina collapsed so that the tunnel of Corti and Nuels' spaces disappeared. As a rule the tectorial

other cases it may be collapsed over the Organ of Corti In all the cases mesothelial cells were agglutinated to the basilar membrane Compression was also visible in the vestibular system where the otoconia agglutinated over the maculae and sometimes the cupulae over the cristae In these structures the height of sensory epithelium seems to be diminished As in the cochlea, the vestibular labyrinth did not present precipitates and globular formation

The cause of the compression phenomenon has been the center of several theories and debates According to Witmaack[4,5] perilymph is produced by a process of filtration, while endolymph is formed by a secretory process which takes place in the stria vascularis, Organ of Corti, cristae, maculae and its marginal epithelium Wittmaack claimed that endolymphatic pressure must be higher than perilymphatic, otherwise the architecture of the cochlear duct could not be maintained Under some circumstances the endolymphatic pressure may be diminished or the perilymphatic pressure may be increased In either case, Reissner's membrane collapses over the Organ of Corti, which will be affected in varying degree, from mild distortion to complete flattening This picture was called "hypotonic degeneration" by Wittmaack who claimed it is essentially a vital process Mygind[6] stated that perilymph is a filtration product mainly of the vestibular region of spiral ligament while endolymph is secreted mainly by the stria vescularis Normally both mechanisms are in balance Mygind found the picture described as hypotonic degeneration by Wittmaack only in animals fixed by intravital perfusion He assumed that because of some caprice of nervous mechanism, filtration predominated over secretion during perfusion of saline Consequently, Reissner's membrane collapsed over the Organ of Corti, causing several degrees of compression He called this picture "endolymphatic compression" and, like Wittmaack claimed it is a vital process Mygind[6] also stated that in human temporal bones the process of autolytic dissolution may induce collapse of the Organ of Corti so that it may be confused with the true compression as previously described

In either theory the factor which brings about the com-

membrane was flattened to a thin lamina, which either collapsed over internal sulcus cells and Organ of Corti (most of the cases), or it was detached from it and agglutinated to Reissner's membrane or the limbus Several degrees of compression were found, from moderate distortion to flattened structures A few examples are illustrated in Fig 7 As this figure shows, the limbus also presented several degrees of

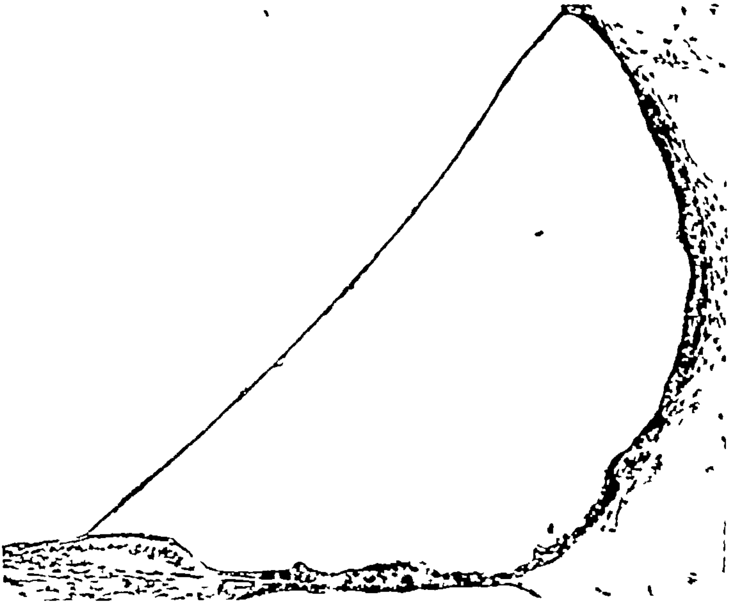

Fig 8 This photomicrograph of the scala media illustrates the neatness of the section in a case of compression of the Organ of Corti Notice the clear cut border of epithelium surfaces and absence of precipitates and/or globules H-E X120

flattening The absence of precipitates and globular formation was characteristic, and gave to the sections an aspect of neatness (see Fig 8) not found even in the best preserved specimens, however, using Mallory's azan stain and observing at high magnification, sometimes a thin layer of agglutinated precipitates could be seen over the Organ of Corti and stria vascularis Surface of the stria vascularis was unusually clear-cut and its flattened epithelium presented many pyknotic nuclei Reissner's membrane occasionally was broken, in

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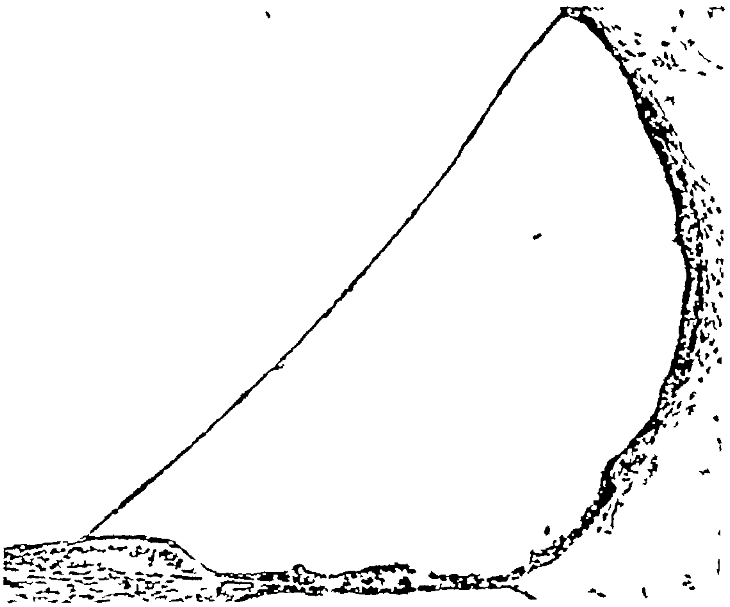

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pression phenomenon in human or animal specimens seems to be mainly the pressure applied over the Organ of Corti We think, as has been maintained in the past,[7] that the phenomenon of compression is an artifact The arguments which lead to this conclusion were as follows

1 Békésy[8] demonstrated that the tectorial membrane and reticular membrane are stiff plates, furthermore, Katsuki and Covell[9] also demonstrated that the reticular membrane with attached pillar cells is particularly resistant to being broken They stated, "The rather firm anchorage of the upper ends of the internal and external hair cells in the reticular membrane and the obviously rigid support of the phalangeal cells and pillar cells tend to produce a unit that is compact and not readily broken up" These observations suggested that a high pressure, which is not likely to be produced in the living state, would be necessary to compress the Organ of Corti It may be argued that a loss in turgescence of cells, as put forward by Wittmaack,[10] might facilitate the collapse of the unit But Katsuki and Covell[9] also found that the body of hair cells can be teased out of the Organ of Corti, leaving their cuticular border with the hairs and reticular membrane intact Schuknecht[11] illustrated in a cat with presbycusis that the frame formed by internal pillar cells and reticular membrane remained in its normal position, even though the external pillar cells and hair cells were absent These observations have shown that large changes in sensory and supporting structures of the Organ of Corti can take place without much altering the frame work formed by reticular membrane and pillar cells This argument supported the theory that the compression phenomenon seems to be related to changes which take place during the histological treatment of temporal bones

2 To explain collapse of the limbus (see Fig 7) by a vital process is still more difficult The limbus is a compact structure made of thick fibers, connective tissue cells and ground substance and it is widely attached to the spiral lamina Studies on presbycusis[11] and acoustic trauma[12] have shown that the connective tissue cells may disappear, but the frame formed by the fibrous tissue remained as in the normal animals These investigations showed that the limbus is particularly resistant to distortion even in the presence of degenerative processes Explanation of the collapse of this structure, as seen in human specimens, by pressure, degeneration, or another mechanism except artifact, is unsatisfactory

3 The absence of precipitates and/or globular formation is very difficult to attribute to any part of a vital process In the best preserved human specimen, and in the best animal sections prepared by intravital perfusion,[1] some debris always was found over the epithelial surfaces or in the scalae The amount of debris increased as autolysis progressed or when pathologic changes were present For these reasons and because the preparations with compression of the organ of Corti are too neat, we doubt this feature of the phenomenon can be produced by a mechanism other than artifact

4 Although the mechanism of dilatation of cochlear duct in Ménière's disease remains unexplained, we may assume that an overpressure probably was developed, but the evidence seemed to indicate that this overpressure is not enough to produce collapse of the Organ of Corti, tectorial membrane and limbus

The reports on histopathology of Meniere's disease,[13] where dilatation of cochlear duct was demonstrated, showed degeneration of the Organ of Corti, but not the features of compression Day and Lindsay[14] reported a case of Ménière's disease of the right ear in which electrocoagulation of the vestibule was done The histologic study of the temporal bone demonstrated dilatation of cochlear duct and a flat Organ of Corti showing some features in common with the compression phenomenon, as Fig 9 illustrates

These changes, which seemed to be degenerative, are incompatible with function, as shown by the audiogram, and the question was raised whether they represented an artifact or a pathologic change Fig 10 illustrates a case taken from our series, in which there was dilatation of cochlear duct without compression of the Organ of Corti and hearing loss as the audiogram indicates

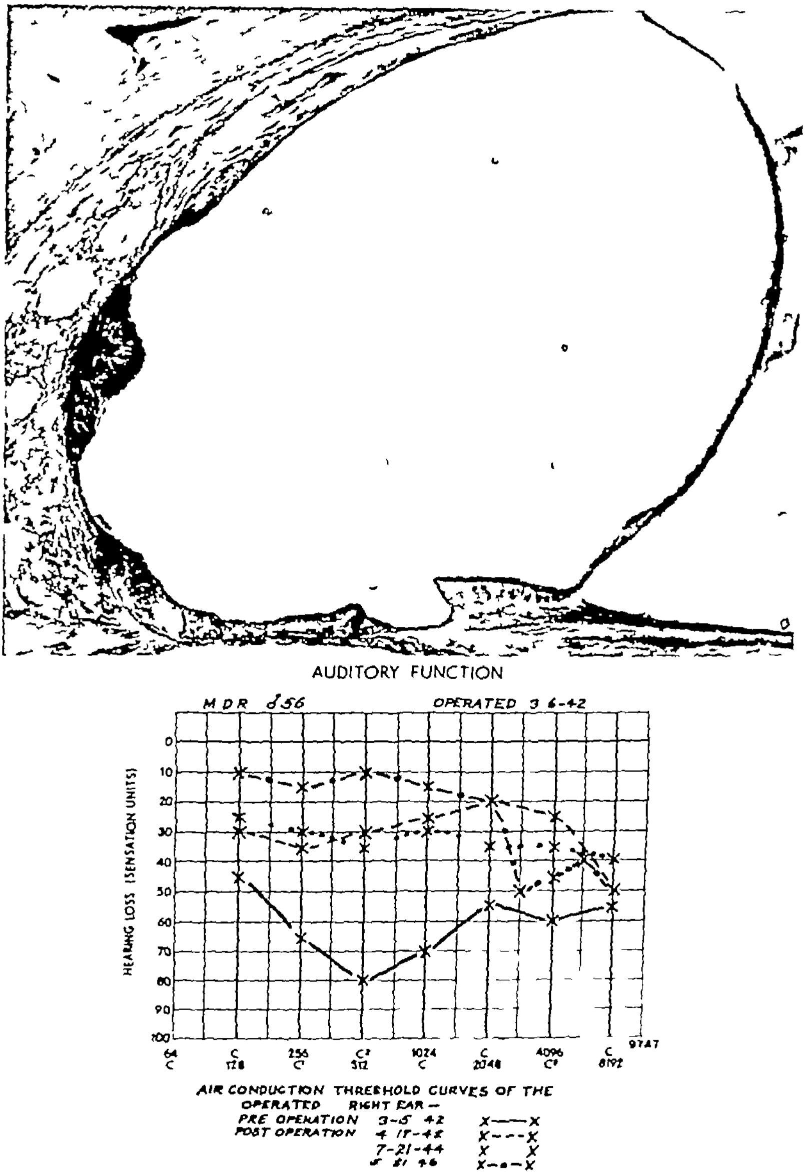
AUDITORY FUNCTION
M D R ♂56
OPERATED 3 6-42
HEARING LOSS (SENSATION UNITS)
0
10
20
30
40
50
60
70
80
90
100
64 C
C 128
256 C'
C² 512
1024 C
C 2048
4096 C⁴
C 8192
9747
AIR CONDUCTION THRESHOLD CURVES OF THE OPERATED RIGHT EAR —
PRE OPERATION 3-5 42 X——X
POST OPERATION 4 17-42 X---X
7-21-44 X X
5 31 46 X-•-X

Fig 9 Organ of Corti of a case of Meniere's disease which was treated by electrocoagulation of the vestibule Dilatation of cochlear duct was found throughout The changes in Organ of Corti are incompatible with auditory function The picture presents the features of compression and the question was raised whether the changes are artifacts or pathologic changes H-E ×115 (Courtesy Dr J R Lindsay)

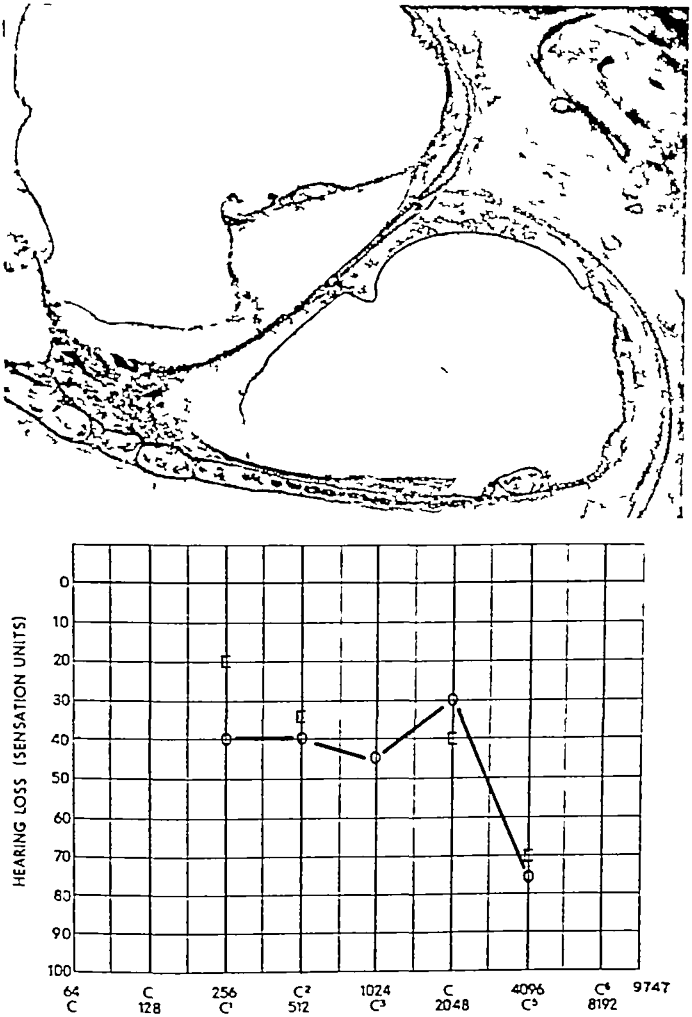

Fig 10 Dilatation of cochlear duct without compression of the Organ of Corti O H 66 years ruptured aortic aneurysm The photomicrograph shows the apical turns (Mallory s azan stain X38) Throughout the cochlea no signs of compression were found in spite of pronounced dilatation of cochlear duct. Notice that tectorial membrane limbus and Organ of Corti retain their shape and also that precipitates and globular formation are present The audiogram was taken 20 days before death

5 If the overproduction of perilymphatic fluid or diminution of endolymphatic fluid brings about the compression, then Reissner's membrane should be found collapsed over the Organ of Corti In Table I the position of the membrane for the 53 specimens is presented Included in Column 1 were all the cases in which the membrane was straight or deviated in one way or the other In Column 2 were those in which the collapse reached only the limbus, in Column 3, all the cases where Reissner's membrane touched the Organ of Corti In most of these cases, the collapse was restricted in extent mainly to the second turn Included in Column 4 were cases in which dilatation of cochlear duct or major distortion of the cochlea by artifacts made it impossible to include them in the other categories In cases with compression of the Organ of Corti (unsatisfactory results) the tendency of Reissner's membrane was to collapse, but the same picture also was found in cases without compression, furthermore, some specimens with compression presented a straight membrane Evidently, collapse of Reissner's membrane can not be used as an indication of overproduction of perilymph or diminution of endolymph The theory of Mygind[6] about the position of Reissner's membrane and endolymphatic compression is not applicable to human temporal bones because only postmortem immersion is used Since the compression, as seen in human material, was similar to that reported by Mygind in animals fixed by intravital perfusion, the theory that it was brought about by perfusion is questionable

TABLE I POSITION OF REISSNER'S MEMBRANE

		1	2	3	4
Results	No Cases	Normal	Collapsed over Limbus	Collapsed over Organ of Corti	Not Classified
Good	18	9	2	6	1
Fair	7	2	1	4	
Poor	6	2	2	2	
Unsatisfactory	22	4	2	13	3

6 If compression is related to pathology or other disturbances of the inner ear, then comparison of the histologic pic-

ture and hearing tests may give some basis for that relationship Audiograms were available for 29 ears In some, the testing was done a few days before death, in others at varying intervals during the year preceding expiration In Table II the results are summarized

Seven of 15 patients with normal hearing, (see Column 1) as determined by the averaging method, presented compression Because these results were not correlative to function (see Fig 11), we believe the compression phenomenon is an artifact It is probable that some diseases of the inner ear present some features of compression, but the relationship of the disease to the histologic findings still must be demonstrated On the other hand, we believe that several times in the past the compression phenomenon has not been identified, or has been confused with pathologic changes For instance, Bunch and Wolff[15] reported three cases of degeneration of the Organ of Corti incompatible with function As far as we can judge from the reproductions, the Organ of Corti presented the features of the compression phenomenon Similarly, Ozaki[16] illustrated a case of streptomycin ototoxicity which had all the characteristics of compression Reissner's membrane appeared to be absent, probably it was broken and agglutinated over surfaces of the cochlear duct Organ of Corti and tectorial membrane were collapsed and the limbus presented a moderate flattening No precipitates nor globular formation could be detected

TABLE II

HEARING LOSS AS DETERMINED BY THE AVERAGING METHOD

Results	No	0-10 db	11-20 db	21-30 db	31-40 db	41-50 db	51-60 db
Good	10	5	2	1	2		
Fair	2	1			1		
Poor	2	2					
Unsatisfactory	15	7	4	2			2
Total	29	15	6	3	3		2

7 The suggestion of Mygind[6] that postmortem changes may induce endolymphatic compression in human specimens is questionable, since the trend of autolytic process is just the

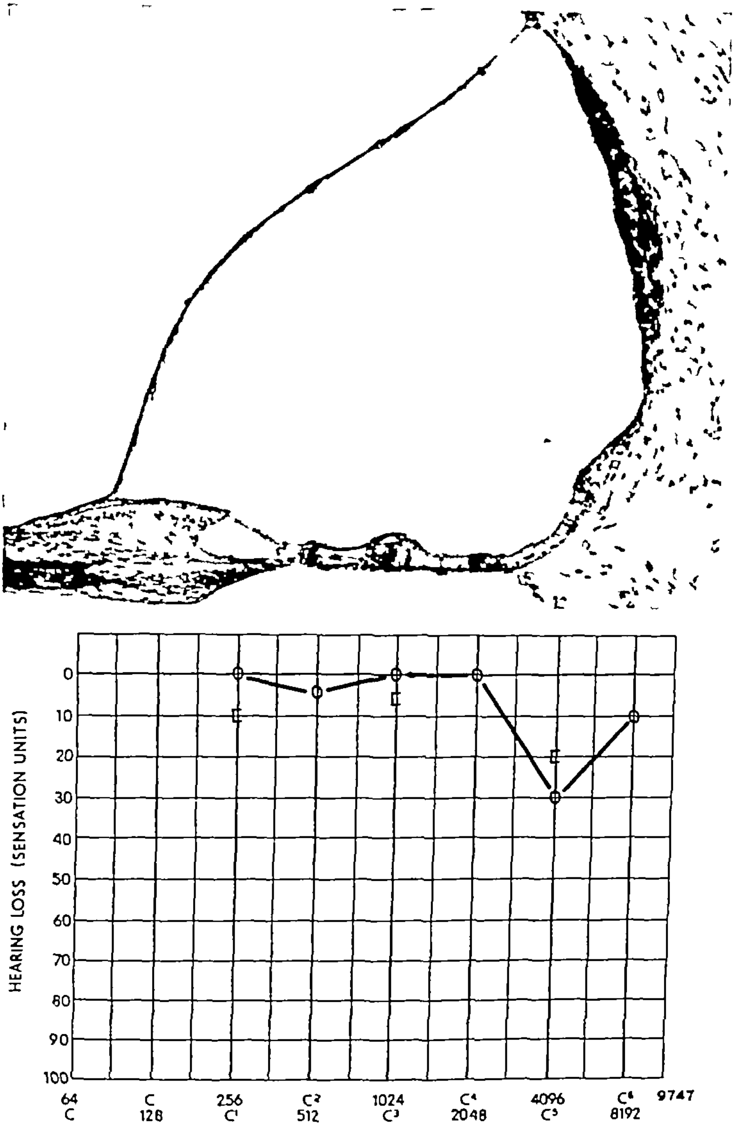

Fig 11 The figure illustrates a case of compression of the Organ of Corti in which the changes are incompatible with auditory function E G 47 years cancer of the tongue The photomicrograph (Mallory s stain X110) shows all the features of compression The audiogram was taken four months before death

opposite, *i e* to produce precipitates, globular formation and disintegration of cells

8 If compression is a vital process, then we would expect to find it in both temporal bones rather than on one side only Of the 25 subjects in which both temporal bones were saved, compression was found to be unilateral in 13 and bilateral in four, furthermore, unilateral compression was accompanied in many cases (8 subjects) by good results in the opposite ear, as Fig 13 illustrates (see legend)

9 The agglutination of mesothelial cells to the basilar membrane, found only in cases of compression, indicates that the phenomenon also took place in scala tympani This finding, and the fact that round window membrane did not show signs of pressure, suggested *that the agglutination of mesothelial* cells to basilar membrane is related more to histologic treatment than to pressure or a vital phenomenon

All these considerations suggested that compression phenomenon is not related to a vital process, as Wittmaack[4,5] and Mygind[6] contended The evidence pointed more to artifacts In the long process of histologic preparations many errors in the technique may be committed, or the interaction between reagents and delicate structures may be different from those expected, and thus marked changes in the cytoarchitecture can be produced In this series, there was no evidence of what kind of error may be committed and no indication as to where in the histologic technique an error may be critical

The arguments supported the theory that compression is an artifact Any effort to prove or disprove this theory is to be desired, because it is of considerable consequence to know whether the phenomenon is an artifact or a vital process

Vestibular Receptors Postmortem changes in the vestibular receptors paralleled those in the cochlea Swelling and pyknosis of sensory cells were the most prominent features In many cases, sensory and supporting cells of margins of maculae were better preserved than the center This may be due to penetrating characteristics of fixatives Precipitates and globular formation were usually found between otoconia and maculae, and also between cupulae and cristae Advanced postmortem changes, as seen in later stages of autolytic process in animals were rare As previously described, compression phenomenon was also detected in the vestibule, however, due to the simplicity of the cytoarchitecture of vestibular receptors, the distortion was moderate relative to that seen in the Organ of Corti

Neural Elements Ganglion of Scarpa was better preserved than the ganglion of Corti, as had been anticipated[1] The degree of postmortem change was not as might have been expected, however In animals the neural elements were the first among all structures of the inner ear to show signs of autolysis Swelling, homogenization, pyknosis, and finally disintegration, was the characteristic pattern In human specimens the picture was different The cell bodies of ganglion of Corti presented swelling and homogenization, pyknosis in a few cases, but no disintegration This probably was due to the fact that autolysis was delayed by refrigeration of cadavers In the ganglion of Scarpa the degree of preservation as a function of time was such that not much difference was seen from one specimen to another Fig 12 illustrates the state of both ganglions as a function of time Two main factors seemed to be involved in the good preservation of the ganglion of Scarpa, one was refrigeration, the other, anatomical arrangement Scarpa's ganglion is in the inner meatus and consequently, readily exposed to fixative

VI PRESERVATION AFTER INJECTION OF FIXATIVE IN THE MIDDLE EAR

This group included 26 specimens In 14 cases the injection time was 15 to 45 minutes, and in 12 cases was 70 to 120 minutes Pre-refrigeration, refrigeration and immersion times were about the same as in immersion procedure The results were classified as 11 good, three fair, one poor and 11 unsatisfactory

Cochlear Receptors The four types of preservation in the Organ of Corti are illustrated in Fig 13 Comparison with the result of immersion procedure showed that for either one

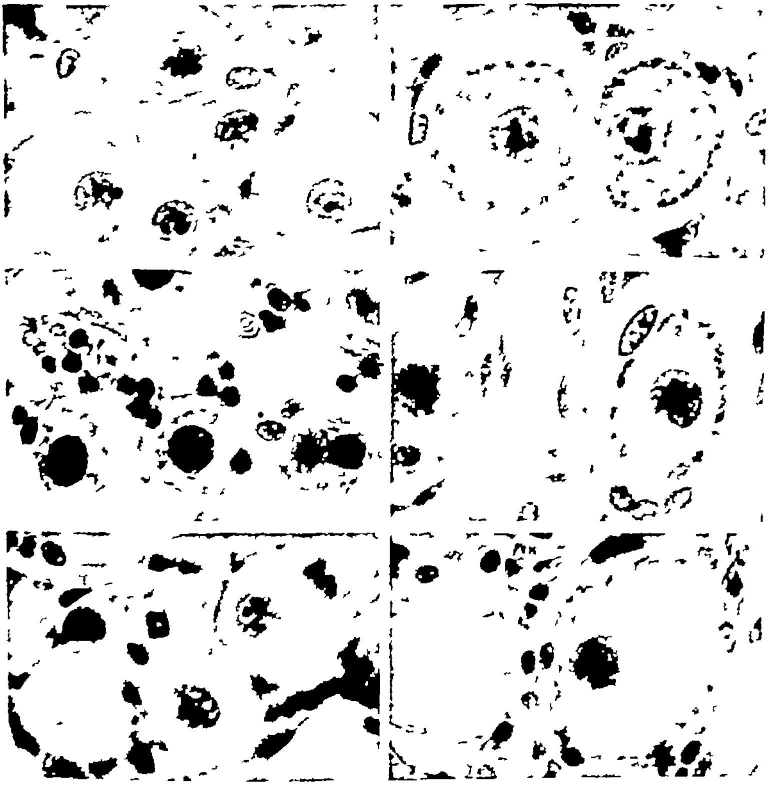

Fig 12 Autolytic changes in ganglions of Corti and Scarpa as function of time found in specimens fixed by immersion procedure From top to bottom on the left, cell bodies of Corti s ganglion of specimens immersed in fixative 7 (X700) 10 (X700) and 20 hours (X625) edema and homogenization are the most prominent features the nuclei are preserved although some may be pyknotic On the right are the corresponding cell bodies of Scarpa s ganglion (X625 X700 and X500 respectively) in which the cell constituents are better preserved than in Corti s ganglion All the sections from which the photomicrographs were taken were stained with H-E

the degree of preservation was similar (see Fig 4) From this point of view there was no advantage of one procedure or the other, however, injection of fixative into the middle ear soon after death gave a higher proportion of well-preserved specimens than was obtained by immersion alone Early fixation helped in preserving the inner ear structures from postmortem changes, but refrigeration still seemed to be the main factor Three observations supported this assumption one, the best results from immersion and injection

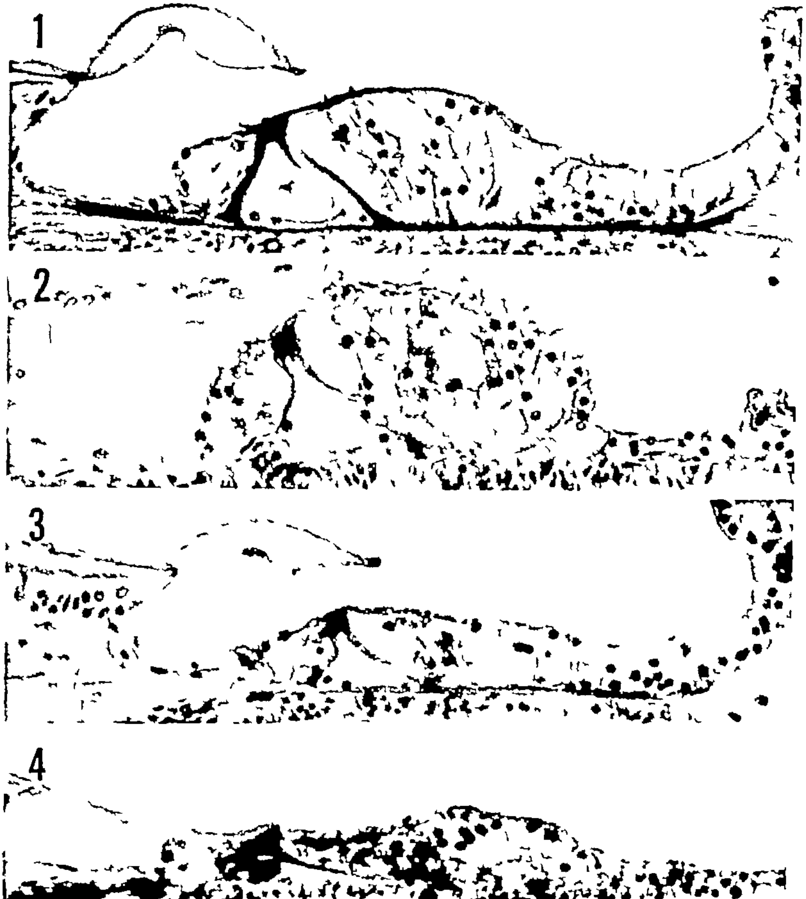

Fig 13 Preservation of the Organ of Corti after early fixation by injecting formalin into the middle ear soon after death 1 Good there is edema in internal sulcus cells and precipitates 2 Fair notice collapse of Reissner s membrane over Organ of Corti without compression 3 Poor edema of cells and intercellular spaces which give a picture of degenerative changes however they are incompatible with auditory function which was within normal range 4 Unsatisfactory compression of the Organ of Corti 1 and 4 belong to the same subject and the audiograms taken 12 days before death gave the same high tone hearing loss on both sides Consequently compression shown in 4 was considered an artifact

procedures are comparable, two, results were as good when injection time was 70 to 120 minutes as when it was 15 to 20 minutes, three, the ganglion of Scarpa, which can not be reached by fixative injected in the middle ear, was as well preserved in this group as it was in the group fixed by immersion only

Postmortem changes, swelling and homogenization of cells, precipitates and globular formation, were as described in immersion procedure

Nine of 11 cases of unsatisfactory results were caused by the compression phenomenon The features were as previously described This observation is in apparent disagreement with the theory that compression is an artifact, because, if early fixation was accomplished by injection, then the inner ear structures should not be affected by subsequent treatment The question is whether one injection of formalin into the middle ear was enough to fix the inner ear structures From basic principles of cytology,[17] a piece of soft tissue of no more than 3 mm in thickness requires 16 to 24 hours to be fixed providing it is completely surrounded by the fluid According to this, fixation of inner ear structures by injecting a fixative into the middle ear must be incomplete, the amount of formalin was small (10 cc), the time of fixation too short

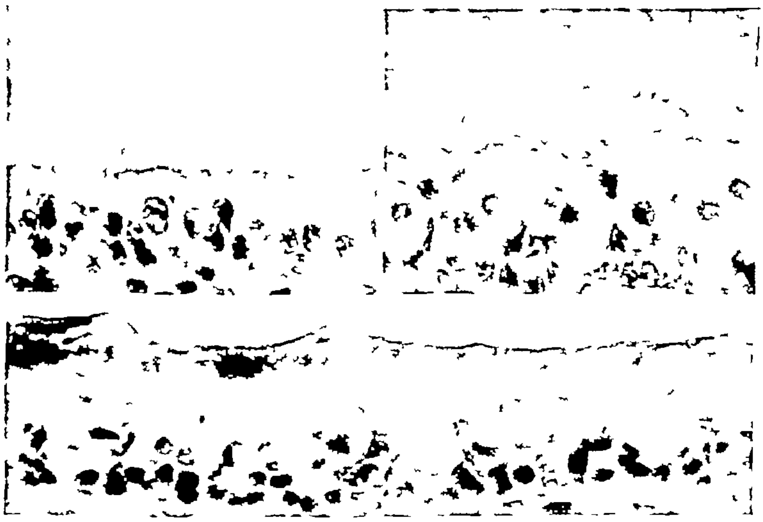

Fig 14 Preservation of macula saccularis after early fixation by injecting formalin into the middle ear soon after death Top left, good right fair bottom unsatisfactory result The latter is due to compression in which the epithelium appears flattened the cells pyknotic and otoconia agglutinated over the macula H-E ×625

(3 to 14 hours) and the structures not completely surrounded by the fixative (round window is the main if not the only pathway) Thus, the conditions under which subsequent treatment of temporal bones was carried out might induce the compression phenomenon

Vestibular Receptors The degree of postmortem changes and the effect of compression upon vestibular structures were of the same order as in immersion procedure In Fig 14 several stages of preservation of macula saccularis are illustrated Notice the effect of compression, the macula was somewhat flattened, and all cells were pyknotic, while otoconia and precipitates were agglutinated over the epithelium Occasionally cell detachment and the first stages of disintegration of the receptors were observed

TABLE III PRESERVATION OF INNER EAR STRUCTURES

As given by removal of the stapes before immersion routine immersion and early fixation by injecting formalin into the middle ear soon after death

Procedure	No	Good	Fair	Poor	Unsatisfactory
Stapes removed	2		2		
Immersion	25	7	2	5	11
Early fixation	26	11	3	1	11
Total	53	18	7	6	22

Neural Elements As in immersion procedure, the elements of cell bodies in Scarpa's ganglion were differentiated, and signs of postmortem changes were minimal in most of the cases Corti's ganglion presented the same pattern of preservation in this group as in specimens fixed by immersion procedure

VII FINAL OBSERVATIONS

In Table III the results of the series are summarized The necessity of improving on histological technique is evident, since about 40 per cent of the specimens were unsatisfactory for studies of fine details, largely because of artifacts

Both procedures, early fixation by injecting formalin into the middle ear and routine immersion, can be improved One injection of formalin, or other fixatives, seems to be insufficient, because a large amount of fluid must be taken up by the tissue of middle ear, and probably some runs out through the Eustachian tube Injections repeated at intervals may be profitable Cadavers should be refrigerated as soon as possible after death, and the temporal bones removed immediately after the cadaver is taken out of the refrigerator

The conditions under which subsequent fixation was actually carried out may increase the progress of postmortem changes first, the wave front of the fixative seems to take hours to penetrate through tympanic membrane, Eustachian tube, oval and round window, and other narrow pathways before reaching the inner ear structures, second, the fixative fluids were used at room temperature (about 25 5° C), and when the specimens were immersed in it heat probably reached the inner ear ahead of the fixative The end result was, most probably, an increase in the progress of autolysis Consequently, subsequent fixation at low temperature (4° C) is a possibility which we are now investigating

From the results obtained in guinea pigs[1] with postmortem perfusion, it was apparent that better fixation would be possible if this method were employed to preserve human specimens Since cadavers can not be perfused, a technique is now being developed to perfuse the temporal bones through the internal auditory artery as soon as the specimens are removed

SUMMARY

The purpose of this investigation was to study the preservation of human temporal bones from postmortem changes and artifacts A study of 53 specimens was made Three histologic techniques were compared removal of stapes before immersion (two ears), routine immersion (25 ears) and injection of fixative into the middle ear soon after death (26 ears) The results were classified as good, fair, poor or unsatisfactory, according to the efficiency of the technique in preserving fine cellular details

Removal of the stapes proved to be no more advantageous

than the other techniques, furthermore, it is not suitable for middle ear studies

Early fixation by injecting formalin into the middle ear soon after death gave a higher proportion of good results than was given by immersion procedure Fair and poor results were mainly due to postmortem changes, while unsatisfactory results were due to artifacts

Several degrees of swelling, homogenization and pyknosis of cells, precipitates, and globular formation were characteristic of autolytic process Disintegration, as seen in experimental animals, was not found even in specimens immersed in fixatives as long as 20 hours after death

Unsatisfactory results due to compression phenomenon were observed in 40 per *cent of the specimens included in the series* Compression was found as frequently in early fixation by injecting formalin *into the middle ear as in the immersion* procedure

Several suggestions were made to improve the current histologic technique

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ALUMNI ASSOCIATION OF THE NEW YORK EYE AND EAR INFIRMARY

The Annual Spring Meeting of the Alumni Association of the New York Eye and Ear Infirmary last April was so well received that it has been decided to expand next year's meeting, which will take place from April 20-23, 1959

Symposia and lectures on Hearing Rehabilitation, Endoscopy, and Ear Surgery will be conducted It is also planned to offer refresher courses in Mastoid and Fenestration Surgery and Stapes Mobilization Techniques

More complete information regarding the meeting will appear in a later issue of The Laryngoscope

than the other techniques, furthermore, it is not suitable for middle ear studies

Early fixation by injecting formalin into the middle ear soon after death gave a higher proportion of good results than was given by immersion procedure Fair and poor results were mainly due to postmortem changes, while unsatisfactory results were due to artifacts

Several degrees of swelling, homogenization and pyknosis of cells, precipitates, and globular formation were characteristic of autolytic process Disintegration, as seen in experimental animals, was not found even in specimens immersed in fixatives as long as 20 hours after death

Unsatisfactory results due to compression phenomenon were observed in 40 per cent of the specimens included in the series Compression was found as frequently in early fixation by injecting formalin into the middle ear as in the immersion procedure

Several suggestions were made to improve the current histologic technique

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TREATMENT OF FRACTURES OF THE FRONTAL AND ETHMOID SINUSES*

HOLLIE E MCHUGH, M D ,

Montreal, Canada

The traumatic disruption of the frontal and ethmoid sinuses, complicated in severe cases by dural tears, loss of brain substance and intracranial infections, presents a problem of management for both the neurosurgeon and the otolaryngologist The degree of involvement of these paranasal sinuses following blunt or penetrating injuries to the forehead, varies from simple fracture lines to gruesome disintegration of the whole frontal area of the skull and its base The success of any plan of treatment can best be assessed in terms of permanent recovery, and the prevention of complications early or late, such as cerebrospinal rhinorrhoea, intracranial aerocele, meningitis or brain abscess

PURPOSE

The purpose of this study is to review the basic principles of the neurosurgical treatment of head injuries associated with fractures of the paranasal sinuses, and to consider the aspects of the problem which are of particular interest to the otolaryngologist The closest collaboration "between those who work below and those who work above the cribriform plate" (Cairns), will best decide the ultimate fate of the patients treated for these injuries

INCIDENCE

Lewin, in 1954 reported that of 1000 consecutive cases of non-missile head injuries severe enough to be admitted to the hospital, 72 (7 2 per cent) were found by radiological examination, or at autopsy, to have a fracture of the paranasal

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*Presented as Candidate s Thesis to the American Laryngological Rhinological and Otological Society Inc 1957

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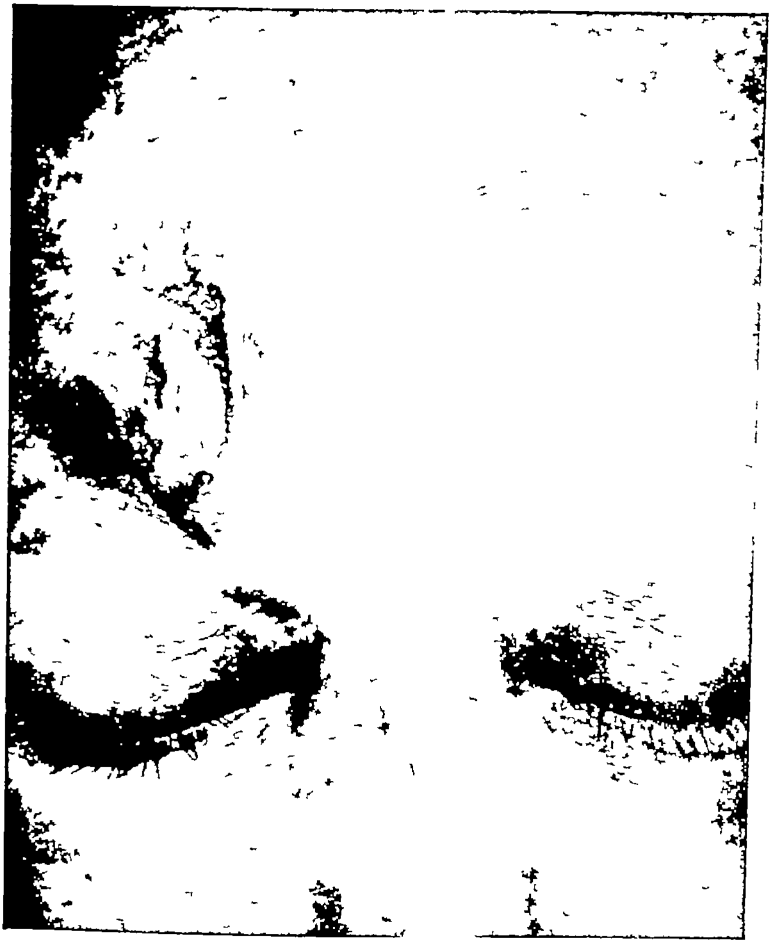

Fig 1 The superficial appearance of the forehead gives no indication of the extent or severity of the deeper damage—Case 3

sinuses It is significant that approximately 20 per cent of the 72 cases with severe frontal injuries died within 12 hours of the injury, and at autopsy the majority revealed dural tears in relation to the paranasal sinuses It is important to note, in less severe head injuries, that dural defects may occur into the paranasal sinuses with or without evidence of displacement of bone fragments, and that such defects constitute a danger which, in the absence of operative inter-

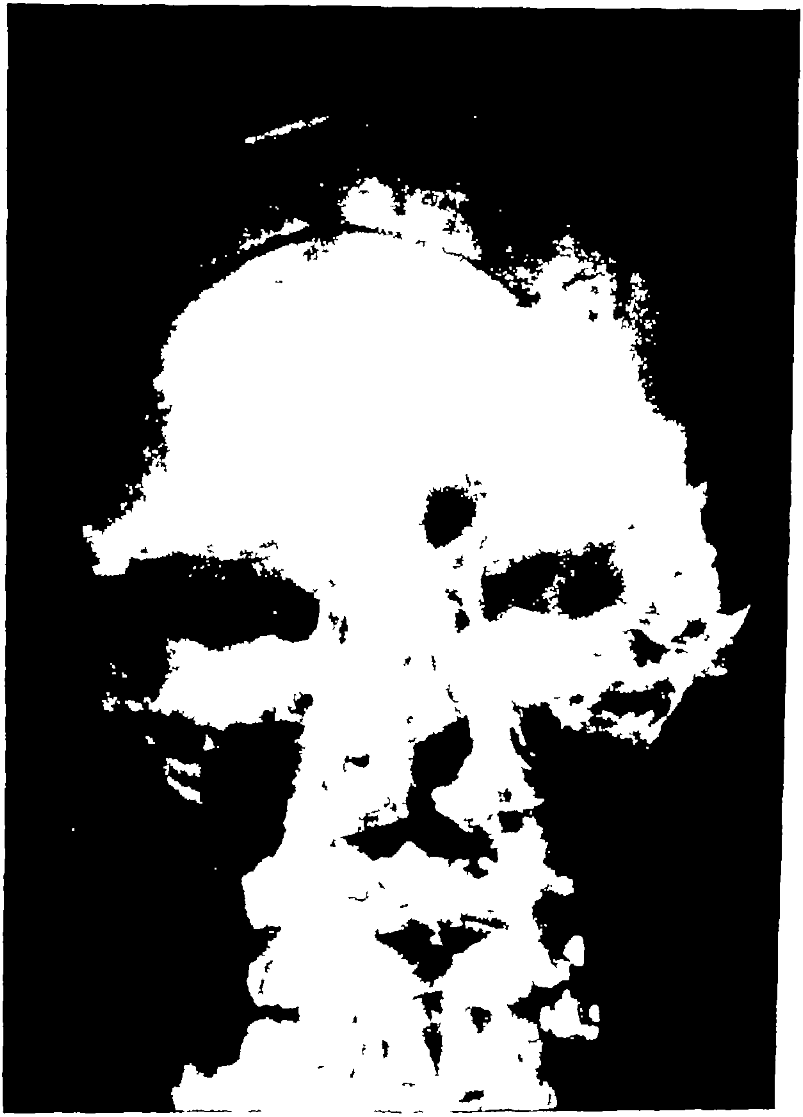

Fig 2 Multiple compound comminuted fractures of the skull with involvement of the paranasal sinuses—Case 3

ference, persist for years after the injury, if not indefinitely (Johnson and Dutt) In all head injuries, and in particular fronto-orbital fractures Cone, Schorstein and others have emphasized that the extent and severity of the deep damage is often considerably in excess of that which the external appearance would suggest (see Figs 1, 2, 3)

All of these cases, therefore, demand the most careful and thorough physical and radiological examinations The otolaryngologist can contribute valuable clinical information by meticulous examination of the ears, nasal passages, turbinates, meatuses and nasopharynx, for sources of cerebrospinal fluid loss or evidence of infection, and his surgical experience and skill can be utilized in the proper treatment of the traumatized sinuses in cooperation with the neurosurgeon

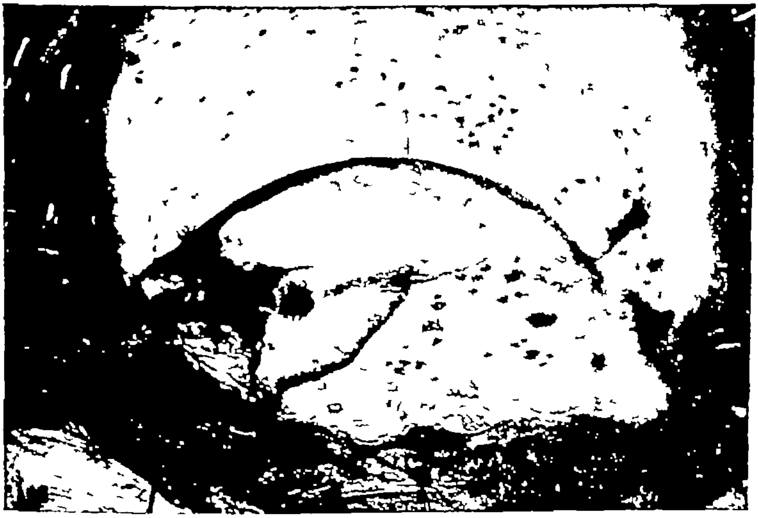

Fig 3 The severely fractured frontal bone area seen at operation Bifrontal scalp flap turned downwards toward the face—Case 3

THE MECHANISM OF FRONTAL AND ETHMOID SINUS FRACTURES

The type of violence that is especially likely to produce fractures of the frontal and ethmoid sinuses is the head-on

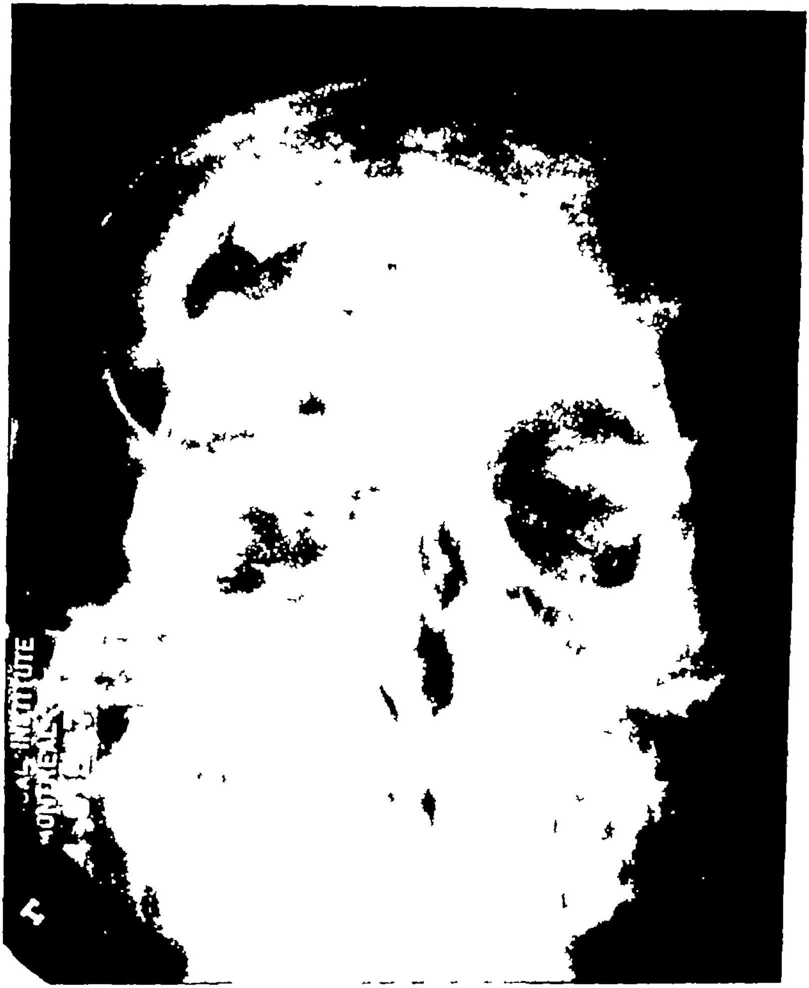

Fig 4 The X-ray appearance of the skull following operation with ablation of the right frontal sinus and exenteration of the right ethmoid sinus—Case 3

blow (Cairns) or blunt injury, in contrast to penetrating wounds The ethmoid sinuses may also be involved in cases where the force of the blow is applied mainly to the facial bones

The factors that determine the shape of the fracture must here, as elsewhere in the skull, include the size and shape of the object that inflicts the damage and the force with which

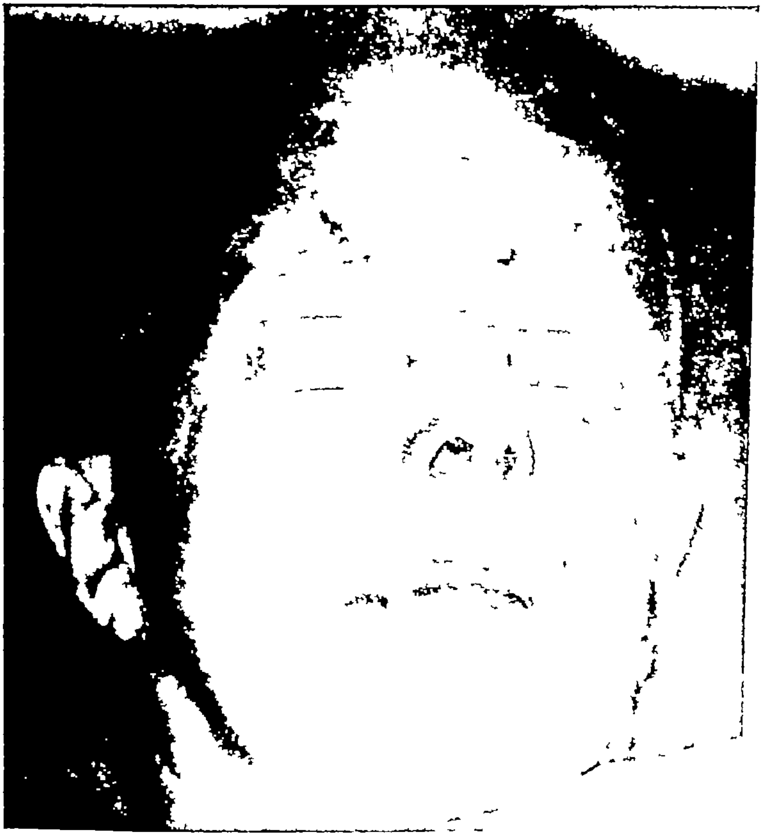

Fig 5 The appearance of the patient after treatment—Case 3

the skull is struck The extent to which the frontal bone is pneumatized must also be an important mechanical determinant (Schorstein)

Fractures involving the frontal and ethmoid sinuses may occur as the result of one or more of the following mechanisms (Schorstein)

1 A force which impinges on the supraorbital arches will, if severe enough, communicate itself to the floor of the anterior fossa and tend to shorten the orbital plate in an anteroposterior direction Should its elasticity be exceeded the bone of the anterior fossa will bend upwards and break, following its natural curvature In this type of direct injury or head-on blow, the dura is lacerated by displaced bone fragments, and defects are found both in the frontal sinuses and the ethmoids, frequently with separation, displacement or complete disappearance of the crista galli (Johnson and Dutt)

2 Fissured fractures may run either in an antero-posterior direction, down across the posterior wall of the frontal sinus and orbital roof or traverse the orbital plate from side to side They are basal bursting fractures, the result of forces striking the vault of the skull above the level of the base Their direction depends upon the direction of the injury and force, and not uncommonly they may traverse the lamina cribrosa and run into a defect in the ethmoids with an overlying dural tear

A fissured fracture will be deflected from a direction determined by the forces which produce it, by irregularities in the thickness of the bone, and will tend to run around and isolate hillocks or blisters of thicker bone (Johnson and Dutt) Fissure fractures tend to run into the nearby foramina in the roof of the cribriform plate and ethmoid

3 A third mechanism may act in conjunction with the two just mentioned the depressed anterior wall of the frontal sinus, by impinging on the brittle posterior wall, may break it over a wide area, including a portion of the anterior fossa floor

TYPES OF FRACTURES AND COMPLICATIONS

In a study of fractures of the skull involving the frontal sinus, Teachenor (1927) was impressed with "the amazing frequency of intracranial complications from this source, and likewise the pleasing success of prompt surgical drainage in the prevention of these complications" Calvert (1942) in discussing injuries of the frontal and ethmoidal sinuses stated that "fractures of the air sinuses are more often productive of grave complications than the literature on the subject would lead one to expect," Calvert emphasized that "the chief hazard in cases of frontal or ethmoidal sinus *fracture is laceration of the dural barrier and spread of infection intracranially from the nose"*

FRACTURES OF THE FRONTAL SINUSES MAY BE

1 Simple fissured or comminuted fractures of the anterior wall of the sinus with or without displacement of bone fragments Fissure fractures may involve the posterior wall without involvement of the anterior wall (Teachenor)

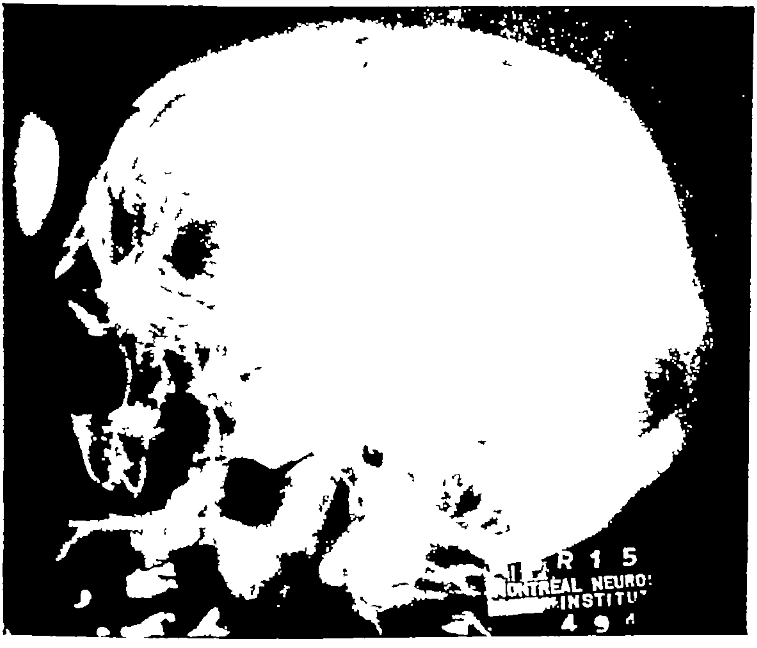

Fig 6 Compound comminuted fractures of the frontal bone with involvement of the anterior and posterior wall of the frontal sinus

2 Compound comminuted fractures of the anterior wall and floor of the frontal sinus with displacement of bone fragments into the sinus (see Fig 6)

3 Severe compound, comminuted fractures with gross bony displacement, dural tears and pulping of brain tissue

Cushing (*1927*) pointed out that mild frontal injuries may,

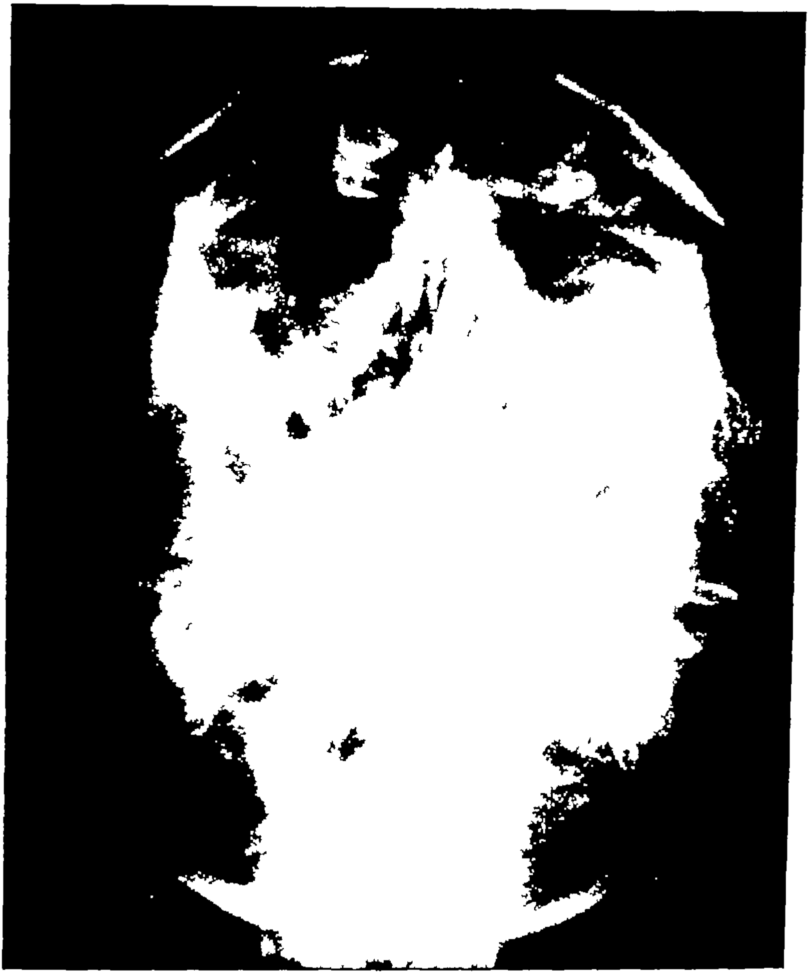

Fig 7 Radiological appearance of the skull with rubber tubes through the trephine openings into both frontal sinuses—Case 1

more often than suspected, produce a fissured fracture of the floor of the anterior fossa, or if not a fracture, a diastasis of the suture between the orbital plates of the frontal bone and the adjacent edge of the ethmoid bone roofing the ethmoid plates

In the floor of the anterior fossa, as in the depressed fractures of the vault of the skull, the dural tear may not always correspond to the fracture line, but will be determined by the sites and degree of fixation of the dura and its relative thickness As it tears, the elastic dura slides over the cortex, and a fold is occasionally entrapped in the fracture line (Johnson and Dutt) The thin adherent dura may be penetrated by displaced spicules of bone or split by distortion accompanying a fissured fracture (McKenzie)

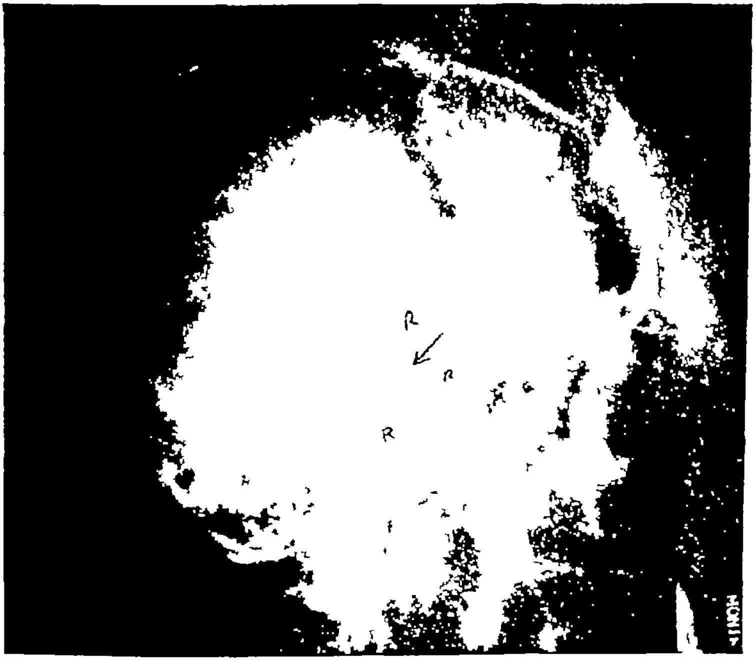

Fig 8 Multiple fractures of the vertex and base of skull with involvement of all the sinuses on the right side with subarachnoid and sub-dural air—Case 2

It is extremely rare for a fissure fracture to cross the ethmoidal roof without producing a defect in the bone and a tear in the dura (Johnson and Dutt) Because the inner periosteum of the cribriform plate is the thinnest part of the dura and, moreover, firmly anchored by its extensions through the bone along the olfactory nerves, Cairns believes that the most dangerous lesion is a fracture of the cribriform plate In such cases there is usually an escape of cerebrospinal fluid from the nose, anosmia may occur, and there is the obvious risk of intracranial infection

In fractures of the frontal sinuses alone the risk of cerebrospinal rhinorrhea and intracranial infection is, in the opinion of Cairns, not so great The dura strips more easily from the bone in this region and, even if it is torn, there is less likelihood that a cerebrospinal fluid fistula will immediately result, because the subarachnoid spaces on the frontal pole of the brain are not so large as on the inferior surface of the frontal lobe The possibility is, therefore, greater that over the frontal pole the defect will be plugged by brain tissue (Cairns)

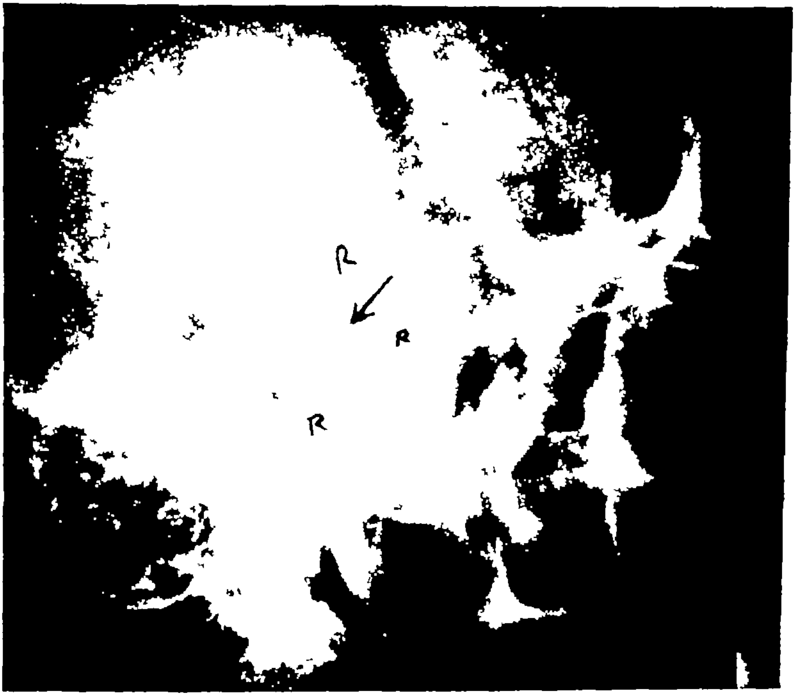

Fig 9 Detail of Fig 7 showing aeroceles and fissured fractures of floor of anterior fossa—Case 2

These opinions are in agreement with Lewis (1928), who stated that dural defects into the frontal sinus, if slight, tended to open the subdural space, but if extensive, communicated with injured brain. Fractures involving the ethmoid region are more likely to open into the large cerebrospinal fluid lakes in the basal subarachnoid space. Lewis believed, therefore, that the risk in the frontal sinus fracture was largely one of abscess or aerocele formation, while in the ethmoidal group the risk was more one of meningitis. (Johnson and Dutt, Cairns and McKenzie).

The two unequivocal signs of dural rupture are leakage of cerebrospinal fluid from the nose and the presence of an intracranial aerocele (Calvert). Cerebrospinal rhinorrhea may follow any type of fracture involving the paranasal sinuses varying from the finest crack, just visible on X-ray, to extensive comminution and depression of the whole frontal area, but not all paranasal sinus fractures are associated with cerebrospinal fluid rhinorrhea, even when the overlying dura is torn (Lewin).

Cerebrospinal rhinorrhea may occur in the acute stage, or as a delayed complication of a head injury. Streams of clear fluid may be seen coming from the middle or superior meatuses in the nose, or on the lateral or posterior wall of the nasopharynx, with the aid of the nasopharyngoscope. A sufficient quantity can usually be collected for analysis by proper positioning of the patient's head, so that the fluid flows or drips from the nose. Cerebrospinal fluid can be recognized by its clear colorless appearance, salty taste, and chemically differentiated from thin nasal secretions by the presence of sugar and the absence of mucin. This type of complication occurred in approximately two per cent of the 1,000 head injury cases reported by Lewin (1954).

Intracranial air and cerebrospinal rhinorrhea are frequently, but not always, associated complications. Air may enter the intracranial cavity through traumatized sinuses and produce an aerocele following sneezing, straining or blowing the nose. Aeroceles may be single or multiple, subdural, subarachnoid, ventricular or intracerebral, and may occur as early or late complications.

Anosmia occurred in approximately five per cent of Lewin's review of 1,000 cases of head injuries It was a symptom in 38 per cent of the cases with associated sinus fractures and in 78 per cent of the cases with cerebrospinal rhinorrhea

The extent of deep damage to the brain substance of the frontal lobes and its relationship to the dural tears, as seen at operation, varies considerably Where there is bone missing as a result of the fracture, the brain may herniate down into the defect and later become firmly adherent to the bony margins This is seen most frequently in the ethmoid region (Lewin) The fracture line may be enlarged by a gradual erosion of the thin margins of bone by the pulsating brain, similar to the changes in bone in contact with an aneurysm In this type of injury the risks of epilepsy as a late complication are of considerable importance

The presence of a nasal-intracranial connection through traumatized sinuses permits an easy pathway to the brain and meninges for infection Meningitis may be an early or late complication, and brain abscess is more frequently a late complication, especially in cases where the fractured sinuses were inadequately treated at the time of injury

GENERAL PRINCIPLES OF TREATMENT

Injuries to the frontal and ethmoid sinuses frequently come within the domain of both the neurosurgeon and the otolaryngologist, "and treatment without appreciation of this fact is not conducive to the best results" (Coleman) The use of sulphonamides and penicillin has lessened the risk of intracranial infection during the acute stages after injury, and it has also effectively lowered the incidence of post-operative infection in these cases (Lewin, 1954)

The basic principles of the neurosurgical treatment of contaminated compound fractures of the vertex of the skull, with laceration of the dura and of the brain, are now standardized and in general use The variations are those of method and timing of operative interference Cone emphasized that "fronto-orbital wounds differ not only from wounds elsewhere in the body, but also from wounds of the vertex with brain injury, because of the intracranial-intranasal connections through the damaged paranasal sinuses"

The basic principles of the rhinological treatment of severe compound comminuted fractures of the frontal and ethmoid sinuses are well established, but the treatment of the simple or apparently less serious fractures of these structures is not so well standardized The treatment of the various types of fronto-ethmoidal fractures will be considered as follows

1 Simple undisplaced fractures of this area may require no treatment (Work, 1954) It has been pointed out, however, that fissure fractures of the posterior wall of the frontal sinus may be associated with dural defects, and that such defects constitute a danger of intracranial infection that persists for years after the injury Although the treatment of simple fractures of the frontal sinuses may be conservative if no infection is present, fractures involving chronically infected sinuses demand prompt and appropriate action to prevent serious complications Cairns stated, however, that "the infrequency of overt sinusitis after injury suggests that intracranial infection can occur, indeed usually does occur through sinuses that are not inflamed" see Calvert, 1942)

Schorstein (1944) commented "at the present time a certain amount of controversy exists as to the need for radical operation in those frontal sinuses where the posterior wall has been broken without a laceration of the overlying skin" He added that some advocate immediate and radical operation, and others a watching policy

Teachenor (1927) advocated prompt surgical drainage of every case of fractured frontal sinus during the acute stage, whether there was leakage of cerebrospinal fluid or not, because "air and infection forced into the frontal sinus from the nasal cavity during sneezing or straining are important factors in the production of complications" In fissured or undisplaced comminuted fractures of the posterior wall of the frontal sinus, a simple trephine opening can be made, with a burr in the under surface of the medial end of the superior orbital ridge, through a small incision just below the eyebrow This permits inspection of the contents of the sinus and of the appearance of the mucous membrane A soft rubber catheter or polyethelene tube can be sewn into place, thus permitting daily gentle irrigation of the sinus with bacitracin or neomycin in solution The purpose of such a trephine is to prevent infection, or air, passing through the sinus into the intracranial cavity This method of frontal sinus decompression has been advocated by Cone for many years, and it has been used in selected cases of less severe fractures of the frontal sinus with success (see Cases 1 and 2) The drainage tube is left in place until the patency of the nasofrontal duct is re-esablished and the instilled solution passes freely into the nose

2 In compound comminuted fractures of the anterior wall and floor of the frontal sinus, the initial debridement may consist of removing bone fragments, providing closure of the skin can be accomplished and the patency of the nasofrontal duct can be established and maintained Patency can be accomplished satisfactorily by an external ethmoidectomy and the use of an acrylic dilator (Work, 1954)

3 If the injury is more extensive and there is comminution and compounding of both the anterior and posterior walls of the frontal sinuses and fractures of the ethmoids, ablation of the frontals and exenteration of one or both the ethmoids is the procedure of choice (Work) If there are dural lacerations and evidence of loss of brain substance the surgical treatment should be carried out completely and finally at the first operation, as early as possible after the injury, by the neurosurgeon and otolaryngologist This concept of primary treatment was strongly advocated by Cone, Stewart and Botterell

In severe compound, comminuted fractures of the fronto-orbital region, with shattering of the paranasal sinuses, tearing of the dura and laceration, contusion and pulping of the brain, Cone removes all of the frontal bone which contains frontal sinus The orbital plates are taken away, the glabella removed, and the orbital fascia is exposed back to the optic foramen and lesser wing of the sphenoid The removal of the ethmoid from above is almost complete, including the perpendicular plates, lamina cribrosa, the crista galli and the os planum The middle and superior turbinated processes come away with the inner wall of the lateral mass The removal is carried back to the sphenoid region The dura is thus exposed widely, the opening in it can be enlarged or new incisions can be made to permit debridement of the damaged brain The new vault of the nasopharynx is the dura and at the sides the orbital fascia The completely free drainage into the nasopharynx and the protection of the dura by packing until all defects are healed, are important factors in this overall method of treatment (Cone) (see Figs 10, 11, 12, 13)

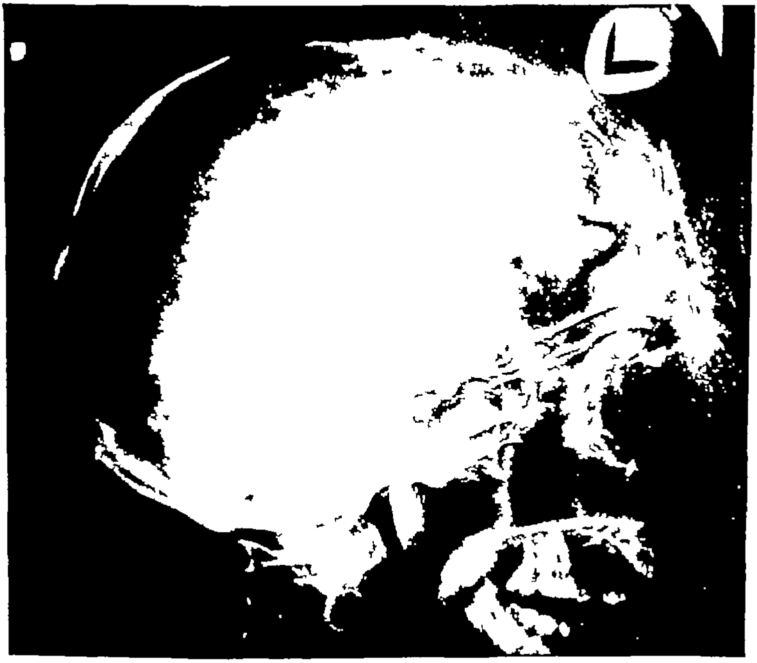

Fig 10 Note the very severe destruction of the bones of the anterior part of the skull and disorganization of the frontal and ethmoid sinuses—Case 5

A series of five cases of head injury with fracturing of the frontal and ethmoid sinuses, and in some cases all of the sinuses, is herewith presented with comments on the type and success of treatment employed

Case 1 Miss L L, age 22 This patient was admitted to Montreal Neurological Institute June 20 1942 three hours after she had fallen from her bicycle and struck her head against a cement abutment She suffered momentary unconsciousness a laceration 4 cm long above the lateral half of the left eyebrow abrasions about the left eye face and side of the neck There was bleeding from the nose but no definite cerebrospinal fluid rhinorrhea

X rays revealed fractures of the left radius and ulna and multiple fractures of the left zygoma left antrum, ethmoid, frontal and possibly

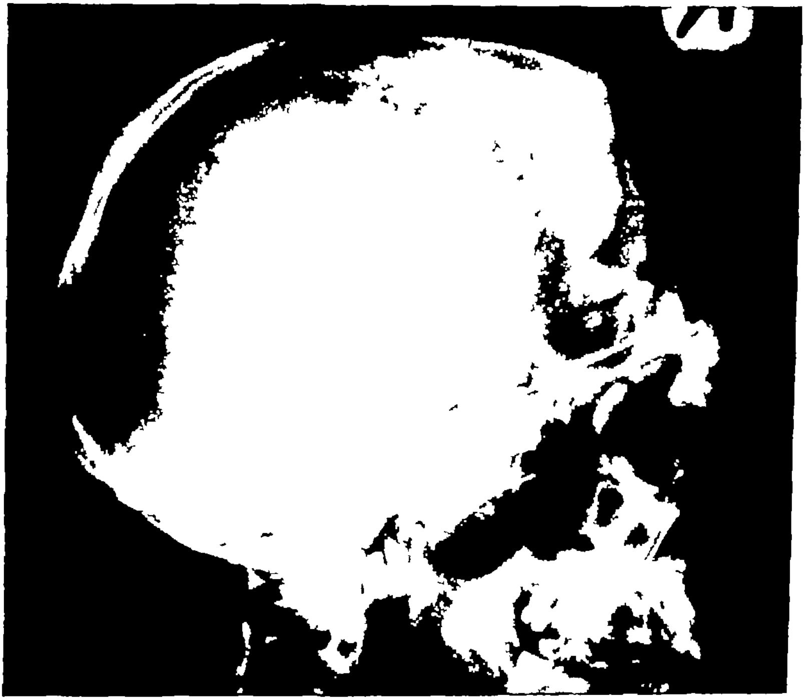

Fig 11 After surgical removal of the grossly fragmented anterior wall of the skull—Case 5

the sphenoid sinuses with no bony displacement in any of these regions There was *a fracture involving the lateral portion of the anterior wall* of the left frontal sinus and there was possible involvement of the posterior wall with no displacement Linear fissure fractures were seen in the floor and roof of the left orbit and in the lateral wall of the left antrum All of the paranasal sinuses on the left side and the right frontal and ethmoid sinuses were cloudy

Neurological Examination revealed a cerebral concussion with no other evidence of damage to the central nervous system

E N T Consultation June 21st No significant findings but in view of the X ray findings a trephine of both frontal sinuses was recommended to prevent if possible serious intracranial complications

Operation June 22 1942 Local anesthesia nupercaine 1 1500 Trephine of frontal sinuses via an incision one-half inch long in the medial end of the eyebrow A Cushing hand operated trephine bur was used to open into each frontal sinus The mucous membrane in the right frontal sinus was thickened pale and polypoidal The nasofrontal duct was blocked by one of the polyps hanging down into its orifice This was carefully removed, and the remainder of the mucosa was left untouched A firm rubber tube was inserted through the trephine opening into the sinus and held in place with dermalon sutures The lining in the left side was only slightly thickened but was ecchymotic in appearance The cavity was filled with blood clot and serous fluid but no definite cerebrospinal fluid A firm rubber drain was inserted as in the right side (see Fig 6)

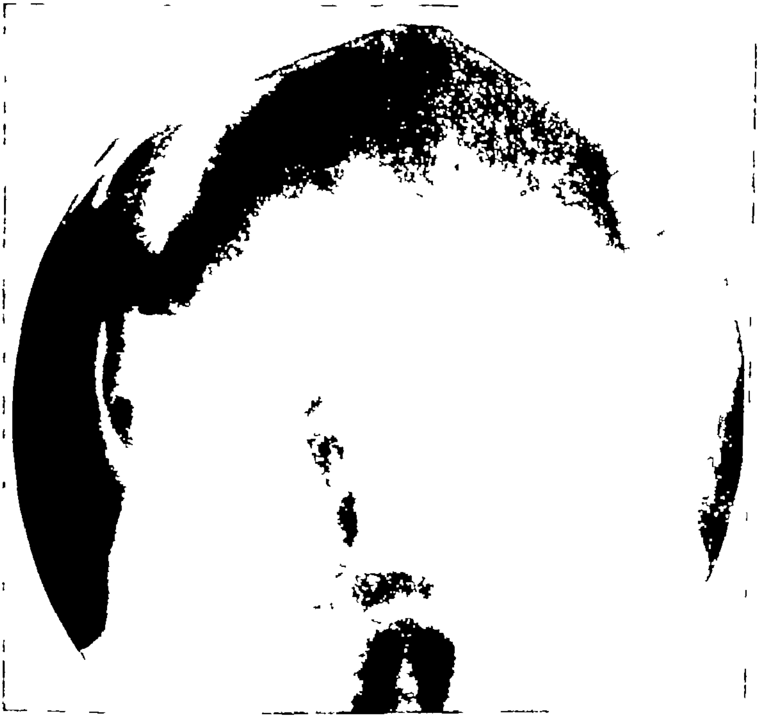

Fig 12 X-rays showing complete removal of the frontal and ethmoid sinuses (Cone s Method)—Case 5

Progress The dressings were changed daily and the frontal sinuses irrigated very gently with triple sulpha suspension On the fourth post operative day the irrigating fluid passed freely into the nose The drains were removed on the sixth post-operative day Sulphadiazine was given by mouth until July 4 Patient discharged on July 14

X rays taken on that date showed marked clearing of the sinuses

Films taken in 1951 showed no sinus involvement and the fractures had healed No complications have occurred since that time

COMMENT

This case represents a multiple uncomplicated linear fracturing of the frontal, ethmoid, maxillary and possibly sphenoid sinuses, treated conservatively with a trephine of both frontal sinuses to prevent possible complications The nasofrontal ducts were apparently blocked until the fourth postoperative day There were no intracranial complications early or late (15 years)

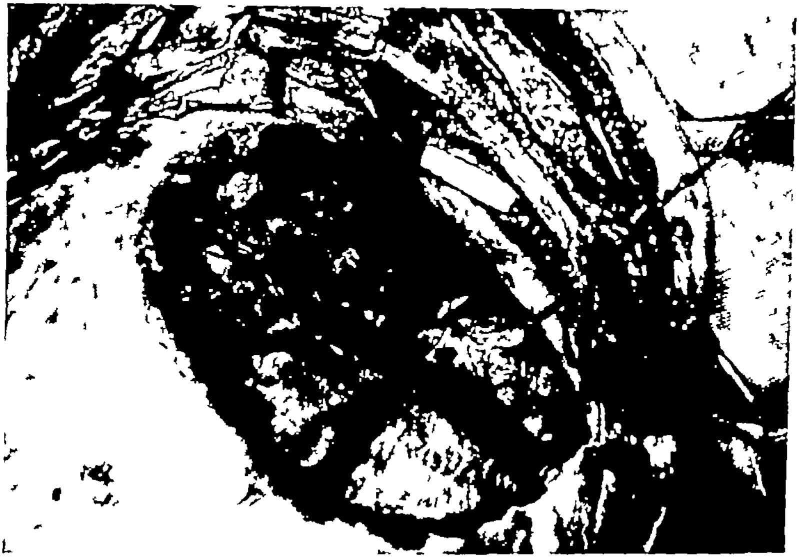

FIG 13 Seen from above All of the frontal bone which contains frontal sinus and compound comminuted bone fragments have been removed Likewise the orbital plates and ethmoid sinuses completely exenterated The dura of the frontal lobe is exposed widely The new vault of the nasopharynx is the dura above and the orbital fascia at the sides

Case 2 Mr G B age 29 This patient apparently fell 70 feet from a tower at 9 00 a m on March 19 1957 and was knocked unconscious He was flown some 1200 miles to Montreal Neurological Institute the same day There was marked swelling and ecchymosis of the eyelids temporal zygomatic and maxillary areas on the right side with a superficial brush burn over the right malar bone He was conscious but irritable and in pain There was no history of bleeding from either ear but he had vomited a large quantity of blood presumably from the back of the nose and paranasal sinuses

Neurological Examination Left abdominal and cremasteric reflexes absent Right plantar upgoing to Gordon s stimulation, no involvement of the cranial nerves

X rays, Skull and Sinuses There were multiple linear fractures of the lateral wall and floor of the right middle fossa and of the parietal and temporal bones and one of these may involve the roof of the middle ear There was air in the anterior fossa over the frontal lobes and possibly over the temporal and parietal lobes on the right side The right antrum was completely dense and both frontal sinuses were cloudy (see Figs 8 9)

E N T Consultation March 19 1967 Some swelling of the right external canal Right drum apparently intact but there appeared to be blood and/or spinal fluid in the middle ear space Nose—evidence of *recent bleeding but no definite cerebrospinal fluid visible In view of* the X ray findings a bilateral frontal trephine and an endonasal antrotomy were recommended

Operation—Bilateral Frontal Trephine and Right Endonasal Antrotomy General anesthesia The mucosa of the left frontal sinus was grossly edematous and ecchymotic in appearance A large fracture line was seen in the roof of the right orbit just posterior to the orbital edge some blood clot in both frontals Soft rubber catheters were inserted into the frontal sinuses and sewn in place with dermalon sutures A large endonasal antrotomy was then performed on the right side

Lumbar Puncture March 22 1957 Pandy trace protein 180 mg per cent, sugar 66 mgm per cent chlorides 733 mgm per cent cells 3000 polys 300 lymphs Daily lumbar punctures for one week and weekly punctures until April 15th showed gradual return to normal of protein sugar color and cell count

Bacteriology All cerebrospinal fluid cultures negative Culture of nasal swab staphylococcus pyogenes

Course in Hospital After drainage of the frontal sinuses was secured it was felt that there was no need for a radical neurosurgical procedure The sinuses were irrigated daily with bacitracin and sulpha suspension On the day of admission he developed a high fever rigidity of the neck and positive Kernig and Brudzinski signs A diagnosis of acute meningitis was made and vigorous systemic and intrathecal therapy was instituted at once This was followed by early clinical improvement and complete return of cerebrospinal fluid findings to normal He was discharged on April 17 1957 on sulphadiazine 0 5 G t i d for two weeks

COMMENTS

A case of multiple fractures of the vertex and base of the skull, with involvement of all the sinuses on the right side, with sub-arachnoid and sub-dural air, and development of purulent meningitis The frontal sinuses were gently irrigated daily until satisfactory intranasal drainage was re-established This occurred first on the left side on the sixth post-operative day and two days later on the right side

The intra-cranial air may have entered via the sphenoids, or via the right frontal and ethmoid sinuses

Case 3 Mr R S, age 50 This patient was seriously injured in an automobile accident April 12, 1950, when his wife drove into the back of a truck parked on the highway They both sustained serious injuries and were taken to the hospital This patient was apparently unconscious for three hours A piece of metal was removed from a laceration on the right side of the forehead and the wound closed He was transferred to the Montreal Neurological Institute on April 15, 1950, for further observation and treatment

Neurological Examination The patient was amnesic after the accident and for a period of about three days Speech was not affected Cranial nerves were intact There was a laceration over the right supra-orbital region, depression of the right supra-orbital ridge and right malar eminence, bilateral periorbital ecchymosis and marked right periorbital edema (see Fig 1)

X rays—Skull Multiple compound comminuted fractures of the skull with involvement of the paranasal sinuses Multiple transverse curvilinear fractures of the frontal bone mainly toward the right side multiple faciomaxillary fissure fractures involving both orbits and including the frontal ethmoid, maxillary and probably the sphenoid sinuses, especially on the right side The right frontal right ethmoid and the left antrum were completely airless there was considerable thickening of the lining of the left frontal left ethmoid and right antrum (see Fig 2)

E N T Consultation April 15, 1950 Ear drums intact and middle ear spaces clear Nasal septum obstructing on the left side, mucosa of the right middle meatus swollen and very moist possible cerebrospinal fluid leak, but no streaming seen, possible cerebrospinal fluid in the nasopharynx 'Decision re exenteration of the right frontal sinus to be made after neurosurgeon had exposed the area and repaired the dural tears"

Electroencephalogram April 15, 1950 "This E E G suggests the possibility of severe brain damage in the right frontal region to a lesser extent the left frontal region and to a considerable extent in the left anterior temporal region"

Lumbar Puncture April 15 1950 Initial pressure 80 fluid bloody

Operation April 16 1950 Bifrontal craniectomy for debridement and repair of compound depressed skull fracture right frontal, right ethmoid bilateral orbital exenteration of right frontal and ethmoid sinuses

Operation Findings Bifrontal scalp incision temporal fossa to temporal fossa reflected forwards The fracture lines were found as seen in the X rays but were much more extensively comminuted and depressed (see Fig 3) The right frontal sinus contained blood and perhaps some brain There was one large and several small tears in the dura of the orbital surface over the right frontal lobe Fracturing of the right anterior fossa involved the right ethmoid sinuses and the orbital roof as far posteriorly as the free edge of the lesser wing of the sphenoid There was no subdural hematoma but some cerebral laceration A number of free fragments of bone from the orbital roof on the left side were comminuted and had lacerated the dura

Gelfoam impregnated with penicillin, streptomycin bacitracin and sulfa crystals was used to fill the spaces between bone orbital fascia and nasal cavity, the left frontal sinus was trephined and a small rubber catheter inserted into the sinus through a stab incision in the eyebrow

Postoperative Course—X rays April 21st The orbital roofs the cribriform plate and the right lamina prapacea of the ethmoid bone were removed and the fragments of bone around the right frontal region adjusted until they are now in quite good position (see Figs 4 5)

May 23 1950 Patient had a remarkably good recovery (five weeks) There was some periorbital swelling on the right side three weeks post operatively associated with some infection (staphylococcus pyogenes) in and about the right sphenoid sinus and in the nose The new roof of the nasopharynx is clean and covered with mucous membrane

E E G May 15th Shows residual severe damage maximum over the right anterior frontal region

COMMENT

This procedure was carried out as an emergency operation four days following extensive compound comminuted skull fracture Its chief purpose was to close the dural defects and prevent intradural septic complications This was accomplished in this case with less radical removal and less deformity than usual

Case 4 Mr M R age 26 This patient was struck by a car and knocked unconscious on August 1 1942 He was semi conscious when admitted to the Neurosurgical Service one hour later He had a contused area above the root of the nose ecchymosis with marked swelling of both eye-lids and superficial lacerations and abrasions of the face body and extremities He was bleeding extensively from the nose and mouth with vomiting of blood at times

Neurological Examination Cranial nerves intact reflexes normal cerebral concussion fracture of base of skull and facial bones

X rays—Skull and Sinuses Aug 1 1942 Multiple fractures involving the frontal bone ethmoid and nasal bones and both maxillae The fracture lines were roughly stellate in the frontal region with the point of convergence in the outer table immediately overlying the left frontal sinus with definite involvement of the frontal sinuses on both sides The major fracture line in the left frontal bone showed no depression There was however quite marked depression of a circular area involving the frontal sinuses nasal bones and ethmoid bones The right antrum was diffusely dense the left antrum relatively clear the sphenoids were clear the lower orbital margins and the roofs of the antra were involved on both sides

E N T Consultation Ears normal nose some deformity and swelling over the bridge and both sides filled with blood and blood clots Blood clots in the nasopharynx throat clear except for postnasal bleeding

Operation, August 1 1942 Through an incision in the left and right eyebrows the anterior and posterior walls of the left frontal sinus were found to be extensively comminuted Loose fragments were present in the posterior wall of both frontal sinuses Both sinuses were filled with blood and clots The mucous membrane was removed from both frontal sinuses The fracture lines were followed back to the posterior ethmoid cells and fragments of bone were removed from this whole area At only one point was the dura opened this was to the left of the crista galli Only a slight amount of cerebrospinal fluid was seen When the debridement was completed a large rubber tube was passed from above down through the nose The cavity left after removal of the frontal sinuses and ethmoid air cells was packed with gauze soaked in sulfona mide and elphamel ointment mixture, a Penrose drain was passed out through a seperate stab wound the incision was then closed carefully

On Aug 14th and 24th the original incision was reopened, the cavity inspected, irrigated and re-packed as in the original operation The hard rubber drain was removed on Aug 14, and replaced by a Penrose drain healthy granulations covered the exposed dura, the visible deformity over the forehead was minimal

On Sept 11, 1942, the patient had a generalized seizure

Encephalogram, Sept 12 1942—Showed a marked general dilatation of both lateral ventricles, also the third ventricle The appearance suggested at least partial obliteration of the subarachnoid space over the surface of the two hemispheres The patient has had no further complications since discharge from hospital Sept 29, 1942

Case 5 Mr M C age 23 On Nov 25 1949, this patient was struck on the forehead by a falling log in a lumber camp He was admitted to hospital in an unconscious state with a compound comminuted fracture of the frontal bones and sinuses Brain tissue was found extruding from the lacerations At operation a frontal skin flap was turned the dura over the left frontal was found torn and the wound filled with bone fragments The dura was apparently not sutured, drains were inserted and the skin closed On penicillin and streptomycin the patient did fairly well until he developed an obvious wound infection He was transferred to the Montreal Neurological Institute on Dec 13, 1949 in a state of stuporous confusion with a purulent discharge from the frontal laceration

X rays—Skull, Dec 13, 1949 A large approximately round fragment of bone containing the upper portions of both frontal sinuses was seen lying in the middle of a large frontal bone defect It was bulging outwards about one cm signifying considerable increase in intracranial pressure There was extreme comminution of the central portion of the floors of both anterior fossa The cribriform plate was markedly comminuted with the medial halves of the orbital plates of the frontal bone There were multiple fractures of the laminae papyracea of the ethmoid of the lesser wings of the sphenoid of the inferior orbital margins, and of the left side of the skull All of the paranasal sinuses were dense

Electroencephalogram Dec 13 1949 'These findings suggest a diffuse destructive brain process in both frontal lobes ' This patient had infected frontal fractures with brain abscess and osteomyelitis

Operation, Dec 13 1949 Pansinusectomy and debridement of the frontal lobe The frontal and ethmoid sinuses were completely removed, *i e* the roof and medial wall of the orbits, the supraorbital ridges the cribriform plate and crista galli (which was floating in pus) the superior and middle turbinates The ostea of the antra were enlarged and the mucous membrane of the antra removed The sphenoid sinuses were entered anteriorly and the mucous membrane removed, all through this intracranial approach The damaged and infected brain and dura was then debrided complete dural closure was found to be impossible The wound was irrigated with sulfa crystals and bacitracin repeatedly The nasal cavity was closed off with gauze packs soaked in the same solution and the frontal cavity packed with gelfoam soaked in the same solution and powdered with bacitracin, the skin was closed with 00000 nylon sutures

Course in Hospital Despite this extensive infection of the bone sinuses and brain this patient did remarkably well, his temperature was 104 on admission and with the aid of penicillin and streptomycin was 99 in two days and it remained down thereafter The nasal packs were removed in two weeks and by the end of six weeks all of the crusts and apparently all of the gelfoam had come away there was no discharge from the nose after three weeks from the time of operation

Eleven months after the accident the patient had a generalized convulsion In the following 18 months he had eight to ten attacks and on March 17 1952 he was admitted to the Neurosurgical Service for treatment Bilateral meningo cortical scars were removed, patient discharged improved

CONCLUSIONS

The incidence, mechanisms and types of fractures of the frontal and ethmoid sinuses occurring in head injuries, and the various complications, have been reviewed and discussed The basic principles of the rhinological and neurosurgical treatment of this particular group of clinical problems have been considered, and comments have been made on the cases presented to illustrate these principles From all this data certain aspects of the problems involved, which are of particular interest to the otolaryngologist, have become apparent

1 The frequency of complications following even simple fissured or comminuted fractures of the frontal and ethmoid sinuses demands recognition

2 The external appearance of the injured area gives no indication of the extent nor of the severity of damage to the underlying bones, sinuses, dura and brain substance

3 Because serious intracranial complications may occur after not only a severe but apparently a minor head injury, when associated with fractures of the paranasal sinuses, all of these cases deserve the most complete and thorough physical and radiological examinations

4 These cases should be examined, evaluated and treated as soon as possible after the injury

5 If there is definite evidence of dural lacerations and damage to the brain substance, it is logical that the surgical treatment should be carried out completely and finally at the first operation, by the neurosurgeon and otolaryngologist working in close cooperation The collaboration of these two specialties will best decide the ultimate fate of the patients treated for these serious injuries

ACKNOWLEDGMENT

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PROBLEMS IN THE DIAGNOSIS OF PHARYNGEAL PARESIS*

JOHN A. KIRCHNER, M.D.,

New Haven, Conn.

Within the narrow confines of the hypopharynx, an area comprising the pyriform sinuses and postcricoid area, one may encounter a surprisingly large variety of disorders producing symptoms. Mechanical obstruction by neoplasm or stricture may produce dysphagia, aspiration, and cough. Narrowing of the lumen by mucosal atrophy in Plummer-Vinson syndrome or encroachment on the lumen by cervical exostoses may interfere with swallowing. Pulsion diverticulum may produce dysphagia, regurgitation, and cough. Increase in the tonus in the cricopharyngeus muscle may cause vague sensations of tightness and choking.

These conditions can usually be diagnosed by a careful history and a combination of physical, neurological, radiological and endoscopic examinations. The exception to this general rule is a disorder which may present a perplexing problem in diagnosis even after thorough investigation with all available techniques, namely, isolated pharyngeal paresis. This condition is usually due to a lesion in the upper portion of the vagus nerve trunk and may be the result of injury by chemical or bacterial toxins, by trauma, tumor, certain degenerative disorders or by localized vascular accidents in the region of the nucleus ambiguus. Supranuclear lesions may also produce dysphagia and voice changes if they involve the corticobulbar tracts of both sides.[1-10]

Pharyngeal paresis may exist in the absence of other neurological disturbances or may precede them and may closely simulate neoplasm of the hypopharynx both by mirror examination and by roentgenogram. Of approximately 15 cases

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*From the Otolaryngology Section, Department of Surgery, Yale University School of Medicine and the Grace-New Haven Community Hospital.

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of nonpoliomyelitic pharyngeal paresis admitted to this hospital during the past three years, five were sent in with an admission diagnosis of carcinoma of the hypopharnx or upper esophagus because of various combinations of dysphagia, "exudate" in one pyriform sinus, "edema" and fullness of one side of the larynx, and other suggestive findings

Curiously enough, the failure to find tumor by endoscopy may still leave the diagnosis in doubt, a fact dramatically illustrated during my internship, in an elderly woman admitted with dysphagia of several months' duration Barium studies were interpreted as showing a space-occupying lesion of the hypopharynx The "filling defect" on X-ray was so strongly suggestive of neoplasm that after esophagoscopy failed to reveal tumor, surgical exploration of the neck was carried out on the assumption that an extrinsic mass was present and was making pressure on the hypopharynx In retrospect, it is obvious that the asymmetry in the barium-filled hypopharynx was due to inadequate emptying by the atonic musculature on one side, particularly since a diagnosis of neurological disease was made before the patient left the hospital

There are certain remarkable similarities between pharyngeal paresis and carcinoma of the hypopharynx in the history, physical and endoscopic examination, and by radiological studies

HISTORY

A Dysphagia This may be present in either condition In carcinoma of the hypopharynx, it results from mechanical obstruction at the esophageal inlet, tends to come on rather slowly, and is noticed first for solids, then for liquids

In pharyngeal paresis, dysphagia results from involvement of the constrictor muscalature of both sides Although complete unilateral paralysis has been shown to be compatible with normal deglutition,[9, 10] many patients with dysphagia present a predominantly unilateral atony of the pharynx on radiological examination with barium It is probable that both sides have been involved in the neurological disorder, but that the weakness is greater on one side This is particularly apt to occur in patients with a previous mild cerebral vascular accident

B Hoarseness A postcricoid carcinoma, which involves the anterior wall of the hypopharynx, may infiltrate the cricoarytenoideus posticus muscle, the strong abductor of the cords This produces a limitation of motion and resultant changes in voice[11] A postcricoid or pyriform sinus tumor may also produce hoarseness by infiltrating laterally and inferiorly to involve the recurrent laryngeal nerve

Vagus nerve lesions located between the nucleus ambiguus and the ganglion nodosum cause paralysis of the cord, usually in a para-median position[5 10]

C Cough and Choking In carcinoma of the hypopharynx, local irritation may produce cough In both tumor and paresis, inadequate emptying of the pharyngeal recesses allows aspiration of the excess secretions with resultant cough

PHYSICAL FINDINGS

A Mirror Examination Indirect examination of the larynx and hypopharynx may be very uninformative Unless a tumor has outgrown the depths of the pyriform sinus or postcricoid space, there may be no view of the neoplasm itself A motionless vocal cord may be present in either condition (see above) Saliva or food lodged in the pyriform sinus on the paralyzed side may look like exudate and may simulate a keratinizing neoplasm

What looks like edema may actually be relaxation and bulging of the atonic musculature of the ventricular band or of the lateral pharyngeal wall This may simulate a tumor deep in the pyriform sinus

B Palpation of the Trachea Palpation of the trachea may reveal forward displacement in either condition In postcricoid tumor by pressure from behind the cricoid, in pharyngeal paresis by relaxation of the cricopharyngeus muscle which usually supports the cricoid tightly against the cervical vertebrae[12] What is more remarkable, the trachea may deviof nonpoliomyelitic pharyngeal paresis admitted to this hospital during the past three years, five were sent in with an admission diagnosis of carcinoma of the hypopharnx or upper esophagus because of various combinations of dysphagia, "exudate" in one pyriform sinus, "edema" and fullness of one side of the larynx, and other suggestive findings

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NEUROLOGICAL EXAMINATION

In both pharyngeal paresis and hypopharyngeal carcinoma the patient may initially show no other sign of disease. Weakness of the other three posterior cranial nerves should be looked for, and movements of the soft palate, tongue, posterior wall of the pharynx, sternocleido mastoid and trapezius muscles observed. Certain disorders of the posterior group of cranial nerves have been described by Schmidt, Avellis, Vernet, Jackson, Tapia, and Collet-Sicard.[11] These syndromes consist of various combinations of dysphagia, hoarseness, dysarthria, nasal regurgitation, and sensory and motor disturbances of the trunk and extremities. They are usually due to obvious neurological disorders and do not present the type of problem in differential diagnosis under discussion here.

RADIOLOGICAL EXAMINATION

This usually consists of a plain antero-posterior view, lateral view of the neck, fluoroscopic study of the barium swallow and comparison of the two sides of the barium-coated hypopharynx during the Valsalva maneuver. Careful radiological examination is probably the most important single measure in the evaluation of pharyngeal paresis of any type.[15-21] Here again, however, there are certain pitfalls.

1. *Lateral Film*. The plain lateral film is one of the most useful views in distinguishing between tumor and paralysis in this area, and yet there may be a soft tissue mass behind the larynx in either condition, in tumor, because of neoplasm, in paresis, because of the anterior sagging of the atonic inferior constrictor muscle or because of spastic contraction of the muscle in supra-nuclear lesions

2 *Barium Swallow Film* "Filling defect" may be deceptive and may represent the normally emptied side of the hypopharynx after the swallow has been completed Fluoroscopic observation during swallowing will show that the radio-opaque side of the hypopharynx is paretic

Since certain individuals tend to use only one pyriform sinus in swallowing a small amount of fluid, the filling ability of both pyriform sinuses must be checked by 1 having the patient turn his head first to one side, then to the other while swallowing, so as in each case to direct the fluid into the opposite pyriform sinus, 2 having the patient swallow a large enough amount of barium to fill both pyriform sinuses at the same time It may be difficult to get the patient to swallow a large mouthful of fluid since he realizes that even small amounts will produce coughing Templeton[16, 17] states that a paretic pharynx will accommodate larger amounts of barium mixture if this is administered while the patient is in a supine position In this position, both pyriform sinuses will fill initially as is shown by Fig 7

Food particles which may have been retained in the pyriform sinus should be looked for before barium studies are done

3 *Valsalva's Maneuver* The Valsalva maneuver, a forced expiratory effort against a closed mouth and nose, may outline the superior edge of a tumor, or it may show ballooning of the atonic side in unilateral pharyngoplegia This is a most useful diagnostic test

CASE HISTORIES

Case I Dr E H 71 year-old dentist admitted with inability to swallow of four days duration

Present Illness—Four nights before admission he awoke from sleep with tightness of the throat moderate intermittent dyspnea and hoarseness on admission he could not swallow even fluids and his voice was hoarse

Mirror Examination—There is puddling of milk and saliva in the right pyriform sinus The right vocal cord is motionless in the midline The right false cord is markedly edematous and there is a grayish mass visible deep in the pyriform sinus below the arytenoid cartilage on the right side

Impression—Carcinoma of the right pyriform sinus or hypopharynx with involvement of the right recurrent laryngeal nerve

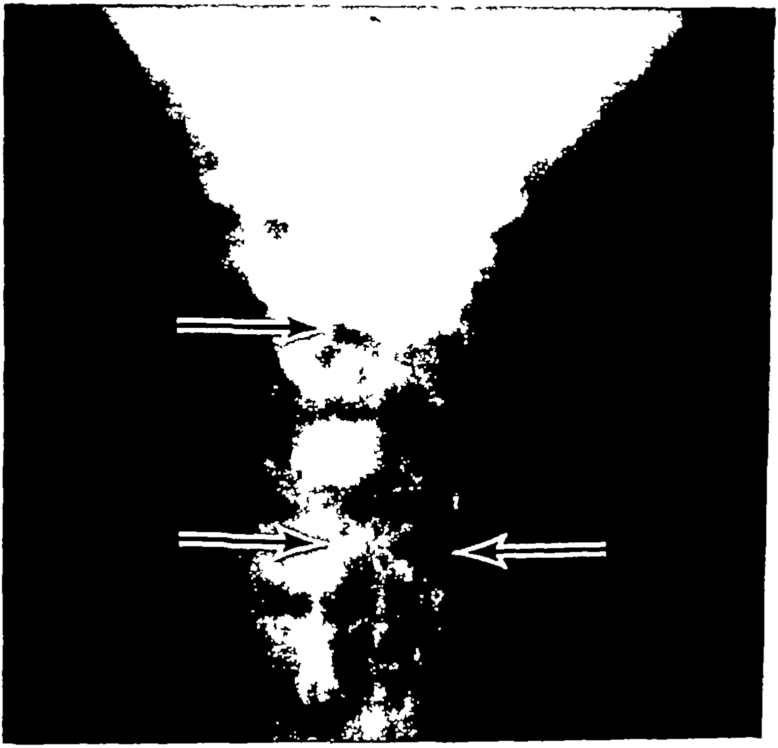

Fig 1 (E H) Irregularly outlined area of radiolucency behind the cricoid cartilage (upper arrow) with puddling of barium in the hypopharynx and valleculae chiefly in right pyriform sinus Dilatation of right pharyngeal wall and deviation of trachea to left (lower arrow) Compare this picture of pharyngeal paresis with Fig 3 retrocricoid carcinoma

X ray—There is displacement of the trachea to the left in the region of the lower cervical and upper dorsal vertebrae no well defined mass is noted In the region of C 5 and 6 there is a soft tissue swelling with an indentation on the posterior wall of the trachea in that area (see Figs 1 2)

Esophagoscopy—Swelling of the right lateral pharyngeal wall at the cricoid level Right cord motionless questionable bulging of the posterior tracheal wall Esophagoscopy negative for mucosal lesion

X ray—(two days after admission) (Thin barium) The valleculae and pyriform sinuses bilaterally show no pathology The contrast medium appears to encounter an obstruction at the level of the junction of the pharynx with the esophagus beyond which no contrast medium is noted in the esophageal passage There is a small amount of regurgitation of barium into the trachea and this is noted in the over-exposed film in the left main bronchus

X ray Diagnosis—

1 Obstruction of proximal most portion of esophagus

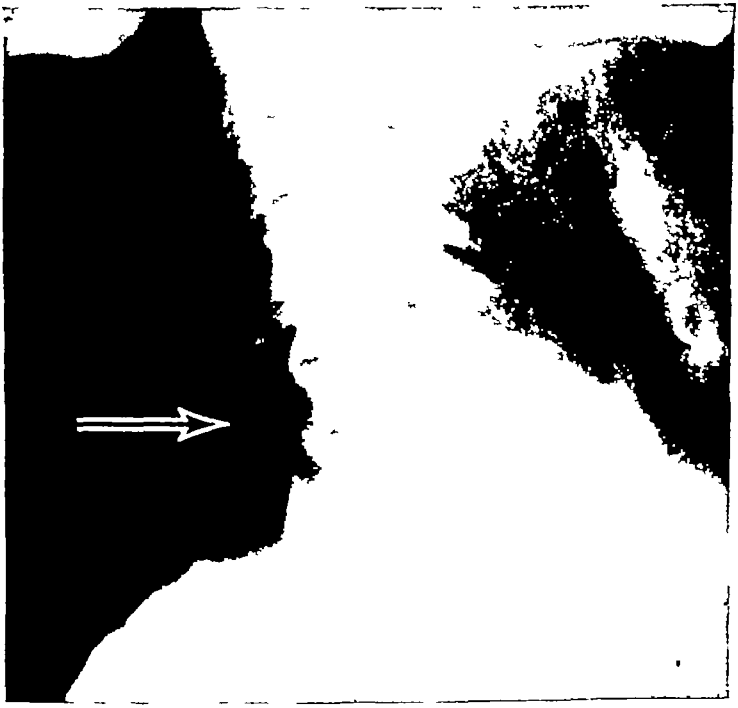

Fig 2 (E H) Soft tissue density in retrocricoid area the result of atony of the cricopharyngeus muscle Compare with Fig 4 retrocricoid carcinoma.

2 Soft tissue mass opposite C 6

3 Hypertrophic osteoarthritis of the cervical vertebrae

ENT Consultation—(Two days after admission) Mirror examination revealed right vocal cord in a para median position voice husky both vocal cords inflamed and swollen probably foreign body which has penetrated the mucosa and is causing pari-esophageal inflammation

Over the next three days the patient gradually improved and was able to swallow a little fluid There was less edema noted in mirror examination of the larynx several large grayish brown masses were coughed up by the patient

X rays—(Six days after admission) There is failure to opacify completely the left pyriform sinus, however, under fluoroscopy this pyriform sinus appeared to be well visualized and not remarkable in any respect The trachea deviates to the left in region of C 6 and 7 There is a small trickle of barium into the esophagus, no evidence of filling defect

X ray diagnosis—Incomplete obstruction of the proximal esophagus, probably due to a central nervous system lesion or secondary edema

Esophagoscopy—(Eleven days after admission), no foreign body or mucosal lesion found

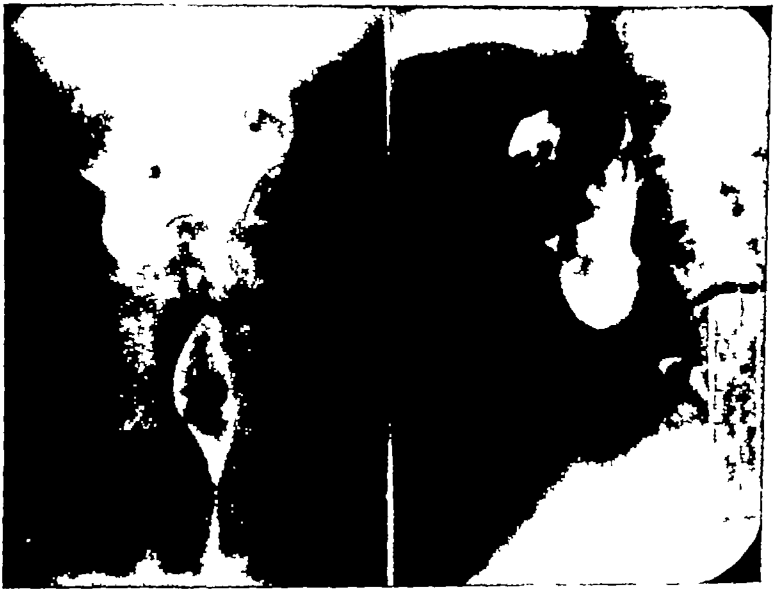

Fig 3 (V W) Valsalva maneuver showing slight dilatation of pharynx particularly of right pyriform sinus in a case of retrocricoid carcinoma Compare with Fig 1

Diagnosis—Bulbar lesion (Vascular) involving Nerves X and IX

After three weeks the swallowing had improved The patient could take a liquid diet and the final impression was that there was a vascular lesion localized in a very small area of the bulb probably an embolus As the patient's temperature was never over 99 2 rectally urinalysis and blood picture normal, it is unlikely that infection was a prominent etiological factor here

Follow up—Two years later this patient had a cerebrovascular accident with temporary paralysis of the left side from which he recovered When check up was attempted five years after original admission he had moved to Florida Voice was said by his son to be adequate but slightly weak, he eats mostly soft food

Discussion—The history, mirror examination, and the initial radiological examination in this case suggested a neoplasm of the upper esophagus or hypopharynx The trachea deviated away from the side of the paralysis and was due in this case, not to pressure from a tumor situated in the hypopharynx, but probably to relaxation of the constrictor musculature attached to the right side of the larynx The "edema" of the larynx seen on mirror and direct endoscopic examination probably represented relaxation and bulging of the atonic inferior constrictor muscle, and accounted for the soft tissue swelling behind the larynx on the lateral X-ray view The grayish mass in the pyriform sinus was identified in this case as retained food (junket), in others as saliva and epithelial debris from the mouth

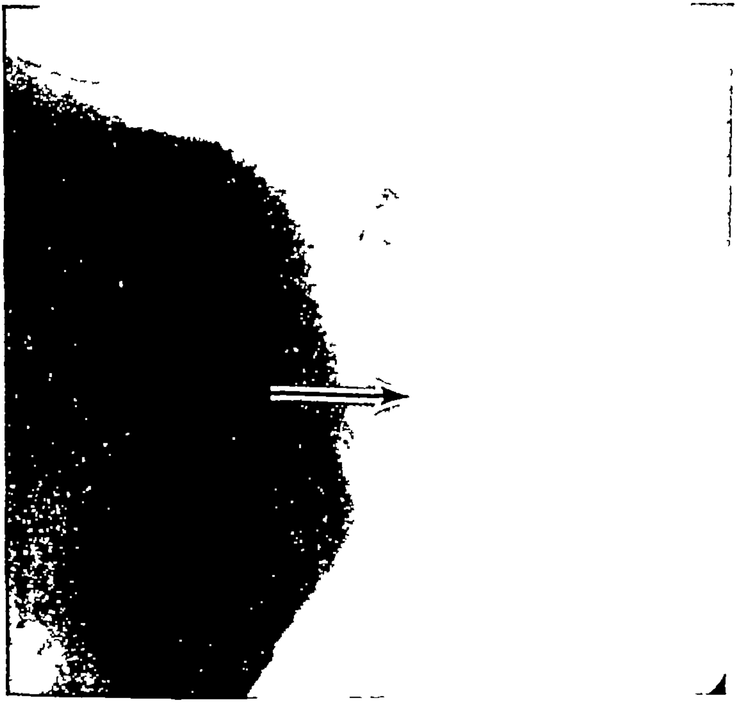

Fig 4 (Y W) Retrocricoid soft tissue density with some forward displacement of posterior wall of trachea Compare with Fig 2 postcricoid carcinoma.

Case II R C 68 year old woman, admitted with chief complaint of hoarseness and dysphagia six months

Present Illness—Six months ago the patient developed hoarseness over a period of a few days Shortly thereafter she developed progressive dysphagia so that she can now take only soft foods and liquids She has lost about 30 pounds over this period of time, has occasional regurgitation of food or liquid into the mouth, has a morning cough productive of yellow sputum

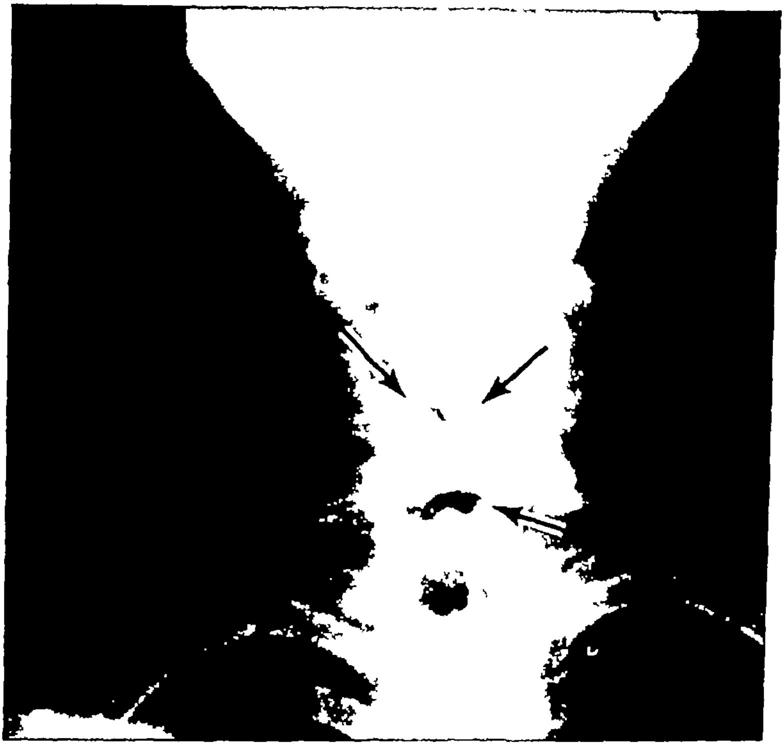

Fig 5 (R C) Irregularly outlined soft-tissue density with retention of barium in valleculae and left pyriform sinus The soft-tissue density in the right pyriform sinus area is illusory and represents the normal hypopharynx after completion of swallow The opposite side both hypopharynx and larynx are paralyzed

Past History—Seven years ago left mastectomy for a carcinoma without lymph nodes One year ago right mastectomy intraductal proliferation without malignancy

Mirror Examination—Left cord is motionless and lies in paramedian position, patient is hoarse There is a collection of saliva in the left pyriform sinus

Physical Examination—Blood pressure 175/110 There is a 0 5 cm nodule under the intact skin on the left in the scar of the mastectomy it is firm and movable Laboratory work showed no abnormalities of the blood or urine Wassermann negative There are no cervical or supra-clavicular lymph nodes palpable The left shoulder droops noticeably and is limited in motion

X ray—Metastatic involvement of dorsal spine L 3 and 4 left sacrum left ileum and left ischium Minimal fibrotic tuberculosis right apex Bilateral apical plaural thickening Poor filling of the right pyriform sinus no displacement of the barium filled esophagus

Diagnosis—Metastatic lesion involving the right pyriform sinus (see Fig 5)

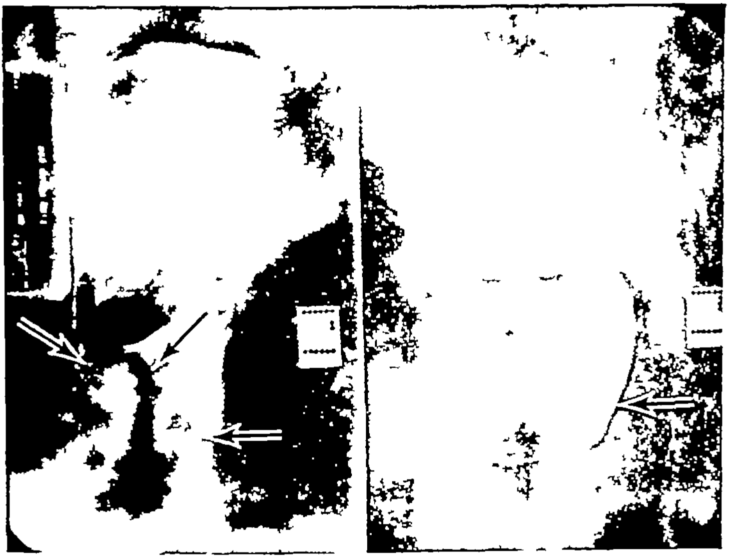

Fig 6 (H R) Film on left demonstrates the pattern which was originally interpreted as soft-tissue mass in right hypopharynx Valsalva maneuver on right half of plate shows dilatation of left pyriform sinus and strongly suggests paresis as the underlying disorder

Endoscopy—No evidence of tumor in the hypopharynx or the upper esophagus The lumen was patent and admitted an esophagoscope left vocal cord motionless

Impression—Bulbar lesion in region of nucleus ambiguus Absence of upper mediastinal mass on X ray with signs of Nerve X and XII involvement suggests central rather than peripheral lesion

Discussion—The X-rays in this case show a failure of the right pyriform sinus to fill with barium Absence of tumor in this area on endoscopic examination indicates that the right hypopharynx is the normal side and has emptied itself normally (see Fig 5) The puddled saliva and residual barium in

Case II R C, 68 year old woman, admitted with chief complaint of hoarseness and dysphagia, six months

Present Illness—Six months ago the patient developed hoarseness over a period of a few days Shortly thereafter she developed progressive dysphagia so that she can now take only soft foods and liquids She has lost about 30 pounds over this period of time, has occasional regurgitation of food or liquid into the mouth, has a morning cough productive of yellow sputum

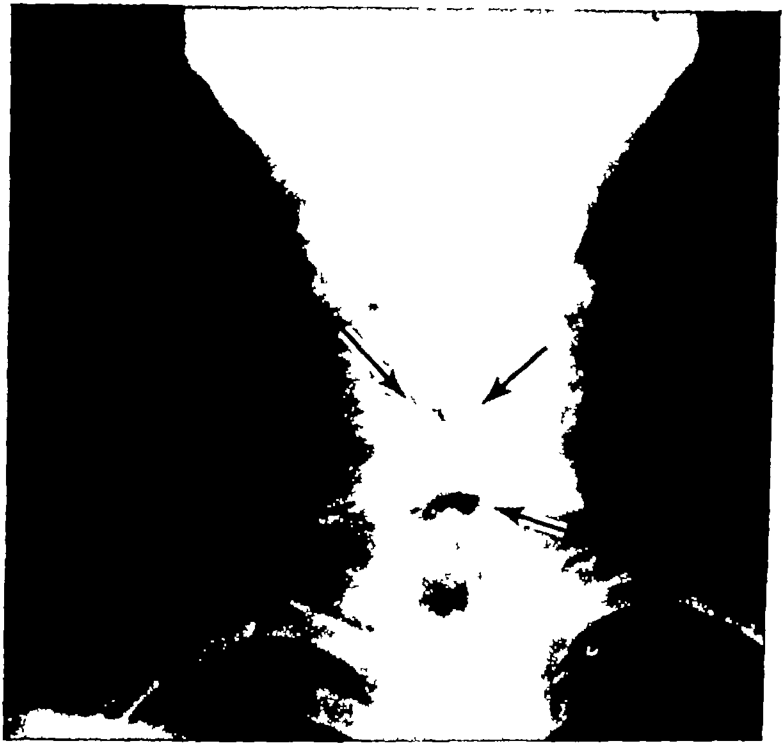

Fig 5 (R C) Irregularly outlined soft-tissue density with retention of barium in valleculae and left pyriform sinus *The soft tissue density in the right pyriform sinus area is illusory* and represents the normal hypopharynx after completion of swallow The opposite side both hypopharynx and larynx are paralyzed

Past History—Seven years ago left mastectomy for a carcinoma without lymph nodes One year ago right mastectomy intraductal proliferation without malignancy

Mirror Examination—Left cord is motionless and lies in paramedian position, patient is hoarse There is a collection of saliva in the left pyriform sinus

Physical Examination—Blood pressure 175/110 There is a 0 5 cm nodule under the intact skin on the left in the scar of the mastectomy it is firm and movable Laboratory work showed no abnormalities of

Mirror Examination—Complete paralysis of left vocal cord puddling of saliva in left pyriform sinus

X ray—Ballooning of entire pharynx Left vocal cord immobile Ballooning of pharynx probably due to involuntary Valsalva maneuver each time the patient attempts to swallow

Impression—Left sided bulbar paralysis with inability of the left pyriform sinus to contract, and immobility of the left vocal cord (see Figs 6 and 7)

During the next six weeks the patient became rapidly worse with progressive atrophy of the muscles of the neck shoulder girdle mandible and both upper and lower extremities A diagnosis of amyotrophic lateral sclerosis was made before he died although involvement of Nerves II and III was felt to be against it autopsy was not obtained

Discussion—Certain degenerative conditions involving the brain stem may be ushered in by dysphagia and hoarseness as a result of involvement of the nucleus ambiguus with resultant paresis of the constrictor muscles and vocal cords Very little else may be found initially, even though weakness and asymmetry of the soft palate and posterior pharyngeal wall are carefully looked for

CONCLUSION

Isolated pharyngeal paresis may simulate carcinoma of the hypopharynx (pyriform sinus and postcricoid area) because of similar findings on history, physical examination, mirror examination and routine roentgenograms with contrast media Endoscopic examination having ruled out an intrinsic neoplasm, pharyngeal paresis can best be demonstrated by fluoroscopic comparison of the emptying-time of the two sides of the hypopharynx during barium swallow, preferably in the supine position, and by the demonstration of ballooning and asymmetry of the muscular walls of the hypopharynx during the Valsalva maneuver

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the left pyriform sinus is the result of atony of the pharyngeal musculature on that side Fluoroscopy and the Valsalva maneuver after barium swallow demonstrate this vividly

Case III H R 68 year old man, admitted with three-week history of hoarseness and dysphagia Preadmission roentgenograms had been interpreted as showing a "tumor of the hypopharynx (see Fig 6)

Endoscopy—The right vocal cord is slightly sluggish There is saliva puddled in both pyriform sinuses and no evidence of neoplasm Patient was discharged without further workup

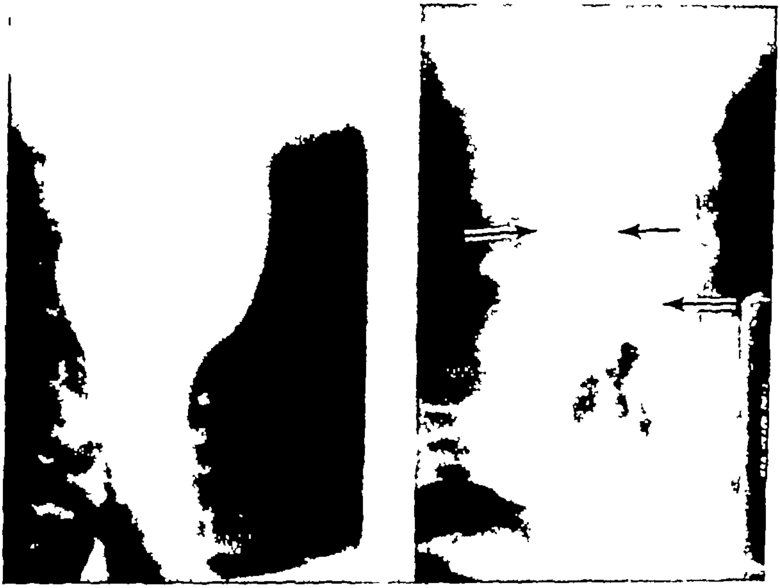

Fig 7 (H R) Barium-filled hypopharynx caught during fluoroscopy in supine position by spot-film (left) rules out a space-occupying mass in right hypopharynx as suggested by Fig 6 and by the right half of this plate The latter shows the normally emptied right side of the hypopharynx immediately after completion of swallow and further supports diagnosis of left-sided pharyngoplegia

Six weeks later he was readmitted because of occipital headache of two weeks duration Four weeks prior to admission the patient had developed weakness of the left eyelid and left arm On admission there was ptosis of the left lid and a dilated reactionless left pupil spinal fluid was negative sputum negative for acid fast bacilli WBC 12 000

Neurological—Patient has a shuffling gait There is evidence of involvement of Nerves III IX and X Vibratory sensation and heat sensation are increased on the right

Impression—Tumor of brain stem or metastases to brain stem from a primary tumor in GI tract or lung

MEDICAL AND SURGICAL TREATMENT OF BELL'S PALSY*†‡

EDMUND P. FOWLER, JR., M.D.,
New York, N. Y.

The best symptomatic descriptions of paralysis of the motor nerve of the face were those made by Sir Charles Bell before 1841,[1] yet the true causes and the best treatments for non-traumatic facial paralysis still remain controversial, and few patients seek early treatment from the few specialists in this field. In order to understand the rationale for the treatments described in this paper, it is necessary to study some of the probable causes of the sudden, usually transient, paralysis of the VIIth cranial nerve, which has come to be known as "Bell's Palsy."

In the common idiopathic form it is generally believed that there occurs an edema which squeezes the nerve trunk so as to block the passage of neural impulses. Cawthorne[2] has described an "hour-glassing" by either a fibrous band or a congenitally small bony ring at the stylomastoid foramen. He, as well as Sullivan,[3] Collier,[4] Kettel[5] and others, have confirmed the observation of Arthur Duel[6] that there is often a marked bulging of the nerve when its fibrous sheath is slit, in cases of classical "Bell's Palsy."

In my small series of seven operated cases, this was most clear-cut in recent facial paralysis, particularly in recurrent facial paralysis, which tends to show a remarkable improvement within a few hours, or a few days, after surgical decompression. I emphasize patients of recurrent facial paralysis, because whether their paralysis has been on the same side or the opposite side, we have, in these patients, a type

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†From the Department of Otolaryngology of the Columbia-Presbyterian Medical Center, New York, N. Y.

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Let us examine the mechanism of how cold could produce facial paralysis We have a theory that this might lead, quite logically, to a common denominator, for all "Bell's Palsy" whether associated with virus infections, allergy, arteriosclerosis or what not

In the mesentery, the conjunctiva of the eye, the chorioallantoic membrane of a chick, the edge of the lung, the spleen and other areas where small blood circulation has been carefully studied, there is no question that chilling will produce local erythrostasis With slight changes of temperature there are produced contracted arterioles and venules also precapillary closures and, in addition, slow moving stasis, or so-called intravascular agglutinations—the "sludge" of Knisely[12] With more chilling, platelets and white cells collect in and along the vascular walls, and eventually the circulation in the region is affected by these intravascular elements, as well This seems to start in the collecting venules, spreads to the capillaries and eventually involves arterioles and arteriovenous shunts, just as does any other local trauma Clinically, this has often been observed in frostbite of the fingers, toes and ears Such erythrostasis in the small blood vessels not only results in anoxia of the part with edema and ground substance changes, but also subsequent susceptibility to milder episodes with slight changes in temperature It is known that similar hypersensitization[13] of nerve tissue can occur, and this may account for recurrent "Bell's Palsy"

Blockage of the small blood vessels with consequent tissue ischemia and secondary edema seems to occur in the VIIth nerve, with many factors other than refrigeration or cooling There may be an association with allergy or infection, thrombi from other parts of the body and with trauma I have seen two cases of peripheral facial paralysis which were otherwise identical with so-called idiopathic "Bell's Palsy," associated with perichondritis of the auricle and swollen lymph glands in the upper cervical chain, another case with granuloma of the external canal, which improved after partial removal of the low-grade infectious process near the exit of the nerve In one case with rubella, the glands were quite large in the region of the stylomastoid foramen, and I have seen another of control, because all of these patients were decompressed within a few days of the onset of their paralysis. In no case of recurrent "Bell's Palsy" have I seen as slow a recovery as occurred for the bout, or bouts, before decompression, whether the palsy was on the same side or the opposite side. In none of my patients with decompressed "Bell's Palsy" has there yet been a recurrence of facial paralysis after decompression. All of them have been done over one year and the oldest one is of 15 years' duration. Similar statements have been made by Sullivan[2] concerning a much larger series of operated "Bell's Palsy." Apparently, in acute cases, removal of bony and fibrous sheaths of the perpendicular part of the nerve within the mastoid relieves pressures and thus often leads to recovery from the paralysis; but is pressure on the nerve, *per se* the primary and only cause of the paralysis?

In 1936, Grunfest[7] reported an experiment with frog nerves and showed that it took 8,000 to 15,000 pounds per square inch to stop nerve impulses when the entire nerve was squeezed in a compression bomb filled with oxygenated mineral oil; however, if there was any bending of axones, neural impulses were reduced or blocked at that point. Perhaps more important, Lewis and his co-workers, Denny-Brown,[4] and more lately Moldaver, working with clips or tourniquet techniques, have shown that any pressure which interferes with the circulation of the nerve itself, will produce suppression of distal neural impulses; and if the ischemia produced by the pressure is kept up for a sufficient length of time, the palsy will be either long lasting or permanent.

What could instigate a primary ischemia in the facial nerve trunk, leaving aside for the moment, secondary edema and swelling? The story that "Bell's Palsy" often follows a cold draft to the side of the face has been generally accepted by most, since the time of Bell. Although this is vigorously denied by a few, the weight of evidence seems to indicate that a cold draft may precipitate the palsy, in some patients. Not so long ago, Sullivan and Smith incontrovertibly showed that cold can produce facial paralysis in rats, but there are undoubtedly other factors and other precipitating agents, as will be mentioned later.

Let us examine the mechanism of how cold could produce facial paralysis We have a theory that this might lead, quite logically, to a common denominator, for all "Bell's Palsy" whether associated with virus infections, allergy, arteriosclerosis or what not

In the mesentery, the conjunctiva of the eye, the chorioallantoic membrane of a chick, the edge of the lung, the spleen and other areas where small blood circulation has been carefully studied, there is no question that chilling will produce local erythrostasis With slight changes of temperature there are produced contracted arterioles and venules also precapillary closures and, in addition, slow moving stasis, or so-called intravascular agglutinations—the "sludge" of Knisely[12] With more chilling, platelets and white cells collect in and along the vascular walls, and eventually the circulation in the region is affected by these intravascular elements, as well This seems to start in the collecting venules, spreads to the capillaries and eventually involves arterioles and arteriovenous shunts, just as does any other local trauma Clinically, this has often been observed in frostbite of the fingers, toes and ears Such erythrostasis in the small blood vessels not only results in anoxia of the part with edema and ground substance changes, but also subsequent susceptibility to milder episodes with slight changes in temperature It is known that similar hypersensitization[13] of nerve tissue can occur, and this may account for recurrent "Bell's Palsy"

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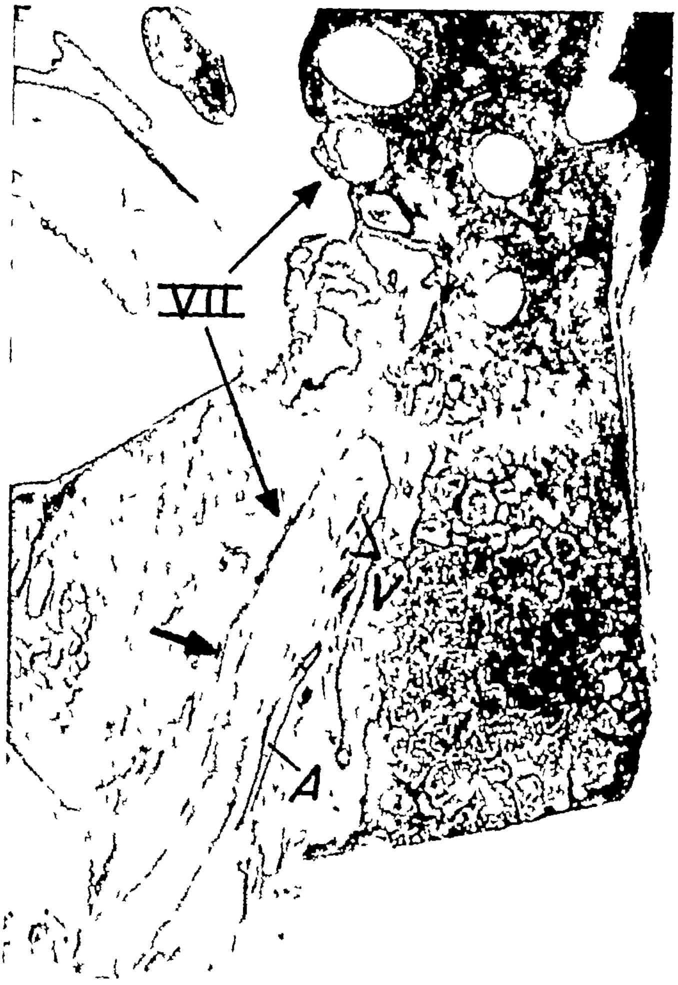

Fig 1 Vertical section through the temporal bone showing the descending part of the facial nerve (VII) as it goes through a normal stylomastoid foramen also a cross section of the nerve near the pyramid Arrow indicates where bony or fibrous narrowing has been observed A indicates artery V indicates veins

case with infectious mononucleosis, with glands in the same region

Sir Charles Bell himself described several cases in which there were abscesses, or large glands in the neighborhood of the stylomastoid foramen[1] Many times the paralysis occurs in patients with diabetes, or arteriosclerosis There are, of course, cases due to injuries from too tight packing in a mastoid wound, or to direct bruising of the nerve

Most otologists have seen facial paralysis with low-grade and seemingly insignificant concomitant serous otitis, or transudative otitis It is possible that these symptoms were due to blockage of the stylomastoid artery, which supplies not only the facial nerve but also the mucous membrane of the middle ear (see Fig 1) I have seen two cases where the bone and the canal were unusually soft but not infected, as described by Kettel[5]

As mentioned above, apparently anything which could lead to erythrostasis in the vessels in the bony facial canal can produce the palsy Even Herpes Zoster of the geniculate ganglion must produce a vascular lesion which produces swelling, ischemia and finally blockage of the nerve impulses, however, all these causes of facial paralysis seem to have a common denominator, namely, erythrostasis and ischemia from spasm, intravascular blockage or external pressure involving the small vessels of the nerve trunk The ischemia causes axone anoxia and secondary tissue edema, which aggravates the situation especially when it can kink the nerve, because anatomical factors such as a fascial collar or a small stylomastoid foramen are present

With this hypothesis as a background, and considerable experience with Menière's disease and sudden deafness, which undoubtedly are precipitated by similar vascular phenomena, it was decided to try vasodilation vigorously, and increased circulation treatment techniques for "Bell's Palsy" To date, the same regimen has been used which had proved successful with Ménière's disease, namely, one-tenth of 1 per cent procaine hydrochloride infusions, twice a day, using 250 cc of a glucose solution, to increase the flow of blood in the small blood vessels, after the patient had been well medicated with nicotinic acid, 50-100 mg 4 i d, p o,[14] to dilate the small blood vessels

We have, as yet, treated an insufficient number of patients to prove, definitely, that this or that regimen helps in a disease like "Bell's Palsy" Our results with a small series are given for what they are worth It has been variously stated that 55 to 80 per cent of "Bell's Palsy" cases recover without treatment Thomas[16] in 1955, published a paper in which he gave the comparison of length of time that "Bell's Palsy" took to recover against a regimen of Cortisone, the average was 24 days From this, and other[16] reviews of the literature, it is difficult to ascertain how the various authors classified their patients with partial, or no improvement I, therefore, indicated in each group how many had no improvement and how many had partial improvement, how many had full improvement, and the average time in which full improvement seemed to occur In all, we studied 100 consecutive hospitalized cases, in which there were sufficient notations in the chart for a report to be made Fourteen were treated with procaine and 86 treated with other methods In the 14 patients treated with procaine, all had considerable improvement, 12, or 86 per cent, had full improvement, two had partial improvement, the improvement occurred within four to 30 days, making an average of 12 3 days Of the 86 controls 14, or 14 per cent, had no improvement, another 12, or 14 per cent, had partial improvement, and the remaining 72 per cent had full improvement, ranging from five days to one year, making an average of 76 1 days Using nicotinic acid alone, there were six patients, two had partial improvement and four had full improvement, in an average of 24 2 days Seven patients had Cortisone treatment, one remained completely paralyzed, two had partial improvement, four had full improvement, in an average of 24 5 days, thus, the nicotinic acid and Cortisone treated cases seem to show better results than the physiotherapy treated cases, however, the nicotinic acid with intravenous procaine seemed to show the best results in this small series

Recently we have been treating our cases of sudden deafness with heparin and cumadin, in addition to procaine and nicotinic acid We have not yet tried this with "Bell's Palsy" but the dramatic improvement in circualtion with heparin, in experimental animals, in addition to that seen with procaine, suggest we should add this medication to our treatment regimen, if we see the patient early enough For the edema, we should, perhaps, use Cortisone as well, at least for a few days In any event, the patient must be hospitalized and the blood chemistry, venous clotting and prothrombin time, carefully controlled In our hospital this has been supervised by Dr Stuart W Cosgriff of the Department of Medicine, and carried out in the same manner as they treat venous thromboses, and as they control hormone therapy afflictions in other parts of the body

If medical treatment does not produce marked improvement in a "Bell's Palsy" in two months' time it has become our practice to decompress the facial nerve, according to the method of Duel,[6] except that a dental drill, under magnification, is used instead of a hammer and chisel More and more, electrical studies suggest that two months is too long to wait

Adequate criteria from electromyograms, chronaxies, and the like, for discovery and evaluation of those patients who will not recover without surgery has been fairly satisfactory in our hands, better prognostic tests are, we believe, urgently needed

Since the patients selected were almost all hospitalized, and, therefore, likely to be severe cases, perhaps our "Bell's Palsy" sample is skew This series, however, shows that watchful hoping, heat, massage and electrotherapy do not provide quick and full relief in a sufficient number of cases Our series compares favorably with the series of Thomas[15] for Cortisone Nicotinic acid is much cheaper than Cortisone, and much safer Perhaps one should use Cortisone in large doses for a few days, and then continue with nicotinic acid and procaine Although the use of i v procaine, plus anticoagulants and steroids, twice daily is difficult and somewhat dangerous, I suggest that further trial of such vigorous early treatment is indicated This paper should stimulate some interest and lead to comparative studies of the relative value of procaine, histamine, steroids, anticoagulants and the like, however, for success, we must persuade all physicians to send in their cases early We believe, "Bell's Palsy" is a medical emergency like sudden deafness, or any other vascular catastrophe If we do not start early we can not expect to eliminate the small blood vessel ischemia and secondary edema Axone degeneration will begin and theoretically we should resort, within a few days to surgical decompression

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RESULTS OF FENESTRATION AFTER STAPES MOBILIZATION.**

ALLAN C. GOODMAN, Ph.D.,*
ROBERT C. BILGER, Ph.D.,†
and
THEO E. WALSH, M.D.,‡
St. Louis, Mo.

Otologists who write on the subject of the stapes mobilization operation are unanimous in stating that this procedure does not adversely affect a subsequent fenestration operation.[1-9] This opinion is based upon surgical and acoustical considerations, as well as upon clinical observations.

The clinical evidence reported as empirical validation of the position that the stapes mobilization procedure does not affect the results of a subsequent fenestration involves from one to 45 cases.[1-9] Meurman,[5] who reports on the 45 cases, states that his group had not been subjected to close study. Werth[9] has analyzed 16 cases in terms of average gain as predicted by the Shambaugh formula, but he did not compare these 16 cases to a group on whom the fenestration operation was not complicated by a prior stapes mobilization.

Because considerable clinical importance is attached to the claimed advantage for the stapes mobilization operation, *viz.* that a subsequent fenestration operation may be performed with no disadvantage in the final result, we felt that a statistical analysis designed to test this hypothesis would be useful.

There are 38 cases in the series of stapes mobilization

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*Hofheimer Audiology Laboratory, Department of Otolaryngology, Washington University School of Medicine, St. Louis, Mo.

†Central Institute for the Deaf, St. Louis, Mo.

‡Department of Otolaryngology, Washington University School of Medicine, St. Louis, Mo.

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operations performed by one of us (T. E. W.), in which a subsequent fenestration operation was performed. This group of 38 cases was compared with a recent group of 227 fenestration operations[10] that were not complicated by prior stapes mobilization. Hearing level* for speech (spondaic words) is the datum that was used to compare the two groups. Residual hearing was used instead of gain, because residual hearing is the most logical measure of success in this context.[12]

TABLE I

Mean Hearing Level for Speech Three Months After Fenestration

	Fenestration after Stapes Mobilization	Fenestration Only
Number of cases	37	227
Mean	26.8	25.7
Standard Deviation	7.97	8.19

TABLE II

Distribution of Cases as a Function of Hearing Level for Speech Three Months After Fenestration

	Fenestration after Stapes Mobilization		Fenestration Only	
Hearing Level	%	No.	%	No.
20 db. or better	23.7	(9)	28.2	(64)
21-25	29.0	(11)	32.6	(74)
26-30	15.8	(6)	18.1	(41)
31-35	18.4	(7)	11.9	(27)
36-40	2.6	(1)	3.9	(9)
41 db. or worse	10.5	(4)	5.3	(12)
		38		227

First, the two groups were compared with respect to mean hearing level as measured three months after fenestration. The mean hearing level and standard deviation for each group of cases are presented in Table I. The difference between the two groups of 1.1 db. in favor of the uncomplicated fenestration group *is not statistically significant* (t = .72, p = .47). One case of stapes mobilization was excluded from this comparison because all hearing was lost after fenestration, and no value could be assigned to hearing level.

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*The term "hearing level" is used here instead of the term "hearing loss" as recommended by Davis, Hoople and Parrack.[11]

In addition to the comparison between mean hearing levels for speech for the two groups, we have tabulated the percentage of cases in each group with residual hearing levels for speech of 20 db or better, 21-25, 26-30, 31-35, 36-40, and 41 db or worse These distributions are presented in Table II with the number of cases involved in each percentage enclosed in parentheses The case of prior stapes mobilization excluded from the comparison between group means, because all hearing was lost after fenestration is included in Table II in the "41 db or worse" interval The two groups were compared statistically with respect to the distribution of cases as a function of residual hearing level, and were found to be not different (Chi-Square $= 3\ 17$, $p = 53$)

The results then, of the statistical comparisons between the group of 38 cases in which a stapes mobilization preceded the fenestration operation, and the group of 227 cases for which the fenestration was not complicated by prior stapes mobilization, indicate that the two groups are not different with respect to mean residual hearing level for speech, or with respect to the distribution of cases as a function of hearing level These results confirm the opinions based upon surgical and acoustical considerations, as well as those based upon clinical experience, that the stapes mobilization procedure does not affect the results of subsequent fenestration

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OSTEOMA OF THE EXTERNAL AUDITORY CANAL

JAMES L SHEEHY, Major,*

Medical Corps, United States Army

"The large solitary osteoma attached by a pedicle to the bony canal wall is an extremely rare condition"[1] The author was somewhat surprised to find this statement during the course of a literature review in connection with another subject[2] Four cases observed during the last two years were called to mind It is the purpose of this paper to define the subject, discuss the treatment, and report these four cases

DEFINITION

Dorland's medical dictionary defines an osteoma as any tumor composed of bony tissue Confusion has arisen clinically[1] between an osteoma of the external auditory canal and the exostosis, which is defined as any bony growth projecting outward from the surface of a bone By definition, any osteoma projecting outward is also an exostosis The confusion is increased by the fact that histologically there is no sharp line of distinction (if any) between a true osteoma and many closely related non-neoplastic hyperplasias of bone[3,4]

From the clinical standpoint it is important that a definition be agreed upon, that the two conditions be considered separately Osteoma of the external canal refers to the solitary pedunculated bony growth, attached to the tympanosquamous suture superficial to the isthmus (see Figs 1, 2) It may be attached to the tympanomastoid suture By contrast exostoses of the external canal are broad-based elevations of bone, usually multiple and bilaterally symmetrical, located deep to the isthmus, at the upper edges of the tympanic bone (see Fig 3)

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*USAREUR Auditory Screening Center and Otolaryngology Section 98th General Hospital APO 34 New York Presently Chief Otolaryngological Section Dept of Surgery Madigan Army Hospital Tacoma Wash

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INCIDENCE AND SYMPTOMS

A number of the current texts[5,6-8] do not mention osteoma of the external auditory canal, exostoses are mentioned briefly Morrison,[9] however, makes a clear-cut distinction between the exostosis and the osteoma, both from the standpoint of location and treatment

Exostoses of the external canal are common lesions, are usually bilateral and multiple, and rarely demand treatment[1,5,6-8,9] They are seen frequently in the course of examinations for other illnesses, and rarely, if ever, produce symptoms

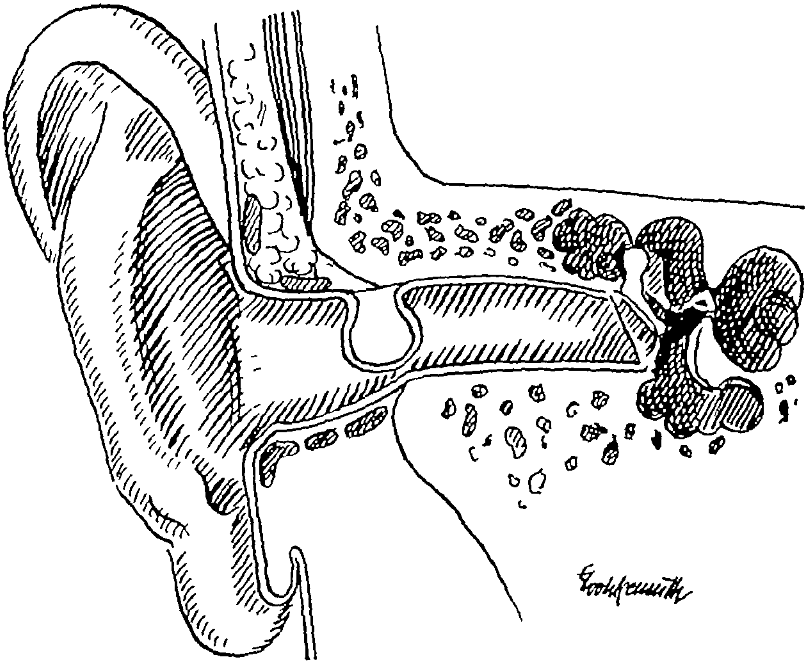

Fig 1 Osteoma of External Canal (Frontal Section)

The external auditory canal osteoma is always a single unilateral lesion and is considered to be rare Kline and Pearce[1] reviewed the literature up to 1954, and stated that it was difficult to say how many of the cases reported (over 37) were actually osteomata, and how many were exostoses

They reviewed in detail the four cases reported during the preceding 15 years, and added a case of their own They concluded that the condition must be extremely rare judging by the paucity of the reports Others agree with this conclusion [10]

Symptoms produced by an osteoma are the result of blockage of the canal Early there may be excessive wax accumulation deep to the tumor A complete block may occur after the introduction of water, and eventually hearing loss will develop, due to blockage by collected debris This often develops before complete occlusion by the tumor Eventually infection supervenes, accompanied by pain Initially the in-

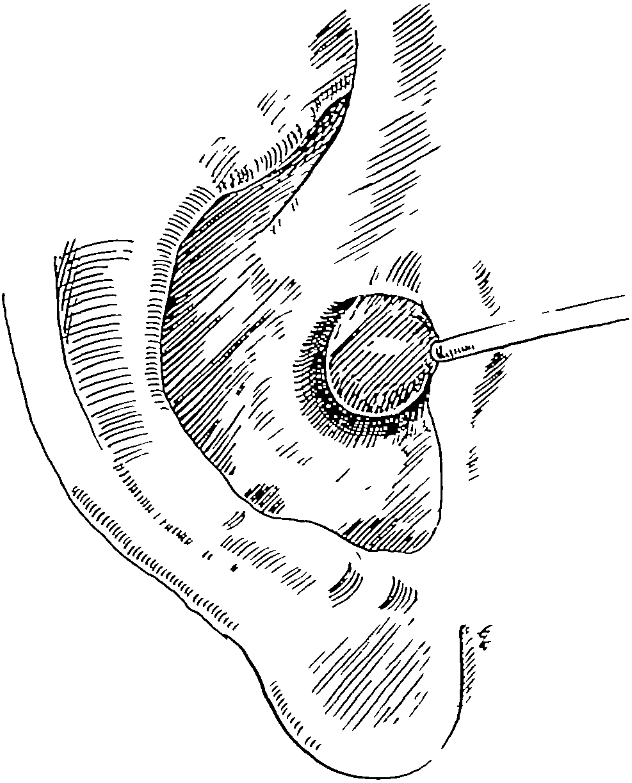

Fig 2 Osteoma of External Canal (Tragus retracted)

fection is limited to the external canal, but it may spread to the middle ear and mastoid A long-standing occlusion and infection will result in finding a situation not unlike a cholesteatoma, with extensive destruction of the mastoid and middle ear, necessitating radical mastoidectomy[1]

TREATMENT

A radical or modified radical mastoidectomy is necessary in an occasional case, to treat adequately the temporal bone suppuration secondary to the blockage by the tumor This was true in two of the five cases reviewed by Kline and Pearce[1] It would seem that modified radical mastoidectomy could have been avoided in two of the cases reviewed by them A simpler (transmeatal) procedure might have been more satisfactory for the patient

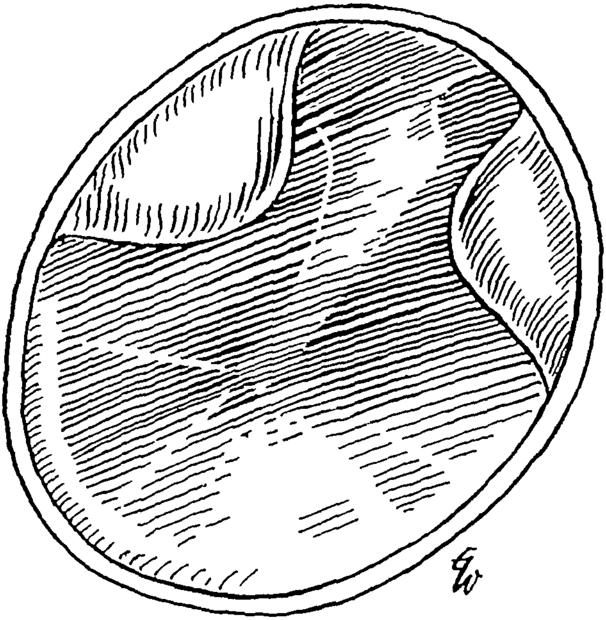

Fig 3 Exostoses of External Canal

Treated early, that is before complications develop, and with an understanding of the anatomy involved, the majority of osteomata may be removed transmeatally An endaural incision may be necessary to facilitate exposure The procedure found most satisfactory in the author's experience is as follows

General anesthesia, with an endotracheal tube, is used The ear is prepared as for mastoidectomy If the outer third of the canal is wide, and the tragus is not excessively prominent, no incision will be necessary Otherwise the upper arm of an endaural incision is made and a retractor inserted A sturdy attic hook or ear curette is inserted past the edge of, and deep to the osteoma (and is later used to deliver the tumor) This can usually be slipped deep to the tumor, even where no opening is visible In an occasional case, posterior canal wall bone may advantageously be removed before inserting the hook An assistant holds this hook A curved gouge is then directed at the pedicle and tapped lightly, loosening the tumor It is lifted out with the hook or curette It may be necessary to curette lightly or burnish the canal wall at the site where the tumor was attached

A small area of canal wall is left denuded If this is less than one-third of the circumference, as it usually is, a skin graft will not be necessary If greater than one-third of the circumference, it is wise to enlarge the canal with the burr, and apply a thin full-thickness skin graft removed from behind the ear The canal is packed with a finger cot filled with vaseline gauze, and a mastoid dressing is applied Any endaural incision is, of course, sutured

Antibiotics are given pre- and post-operatively The packing is removed on the third day, and a dry (powder) treatment is utilized thereafter until healing takes place

One last word on treatment an osteoma of the external canal as herein defined should be removed, even though not causing symptoms This tumor is in a position where it is continually exposed to trauma Continued growth of the tumor may result in complications necessitating radical mastoid surgery Surgery undertaken after the onset of complications is never so satisfactory

CASE REPORTS

Case 1 A 25 year old white male was referred because of a two year history of a gradually enlarging growth in the right ear canal Wax and water would collect deep to it Examination showed a bony tumor attached to the anterior superior bony wall, superficial to the isthmus, filling all but one mm of the canal diameter Hearing was normal

Under endotracheal anesthesia the upper arm of an endaural incision was made to facilitate exposure A small dull ear curette was passed deep to the lesion, which was seen to be attached by a broad pedicle to the tympanosquamous suture It was dislodged by a firm blow on a curved gouge the blade of which had been placed at the pedicle, and was delivered with the curette The tympanic membrane was normal The incision was closed and the canal was packed with a finger cot filled with vaseline gauze A mastoid dressing was applied The dressings were removed in three days, and the canal was healed in two weeks

Case 2 A 22 year old white male was referred for treatment of recurrent otitis externa Examination revealed a subacute right external otitis, due apparently to vigorous attempts by the patient to remove wax from the ear There was a small (3 mm) pedunculated bony tumor attached antero superiorly at the junction of the bony and cartilaginous canal

Removal of the tumor was advised after the otitis had subsided The patient refused treatment

Case 3 A 27 year old Negro male was referred because of a one and a half year history of intermittent discomfort in the left ear Hearing loss had been constant, and amounted to 40 dbs (conductive) Examination revealed a complete block of the left external canal by a bony growth which was attached by a pedicle to the posterior superior canal wall superficial to the isthmus

Under endotracheal anesthesia an S shaped endaural incision was made The membranous canal was separated for a short distance to the pedicle and cut to this point An external cuff of membranous canal was then fashioned, based inferiorly, and turned anteriorly With a bur some of the posterior canal wall was taken down until the pedicle could be seen clearly A sturdy attic hook was then passed deep to the osteoma The tumor was dislodged, using a mallet and curved gouge and delivered with the hook There was much epithelial debris impacted beneath this The tympanic membrane was normal The upper arm of the endaural incision was closed, the external cuff was thinned and replaced and the canal was packed with a finger cot filled with vaseline gauze A mastoid dressing was applied

The dressing and packing were removed in three days, and the canal was healed in three weeks Post operative audiogram revealed normal hearing

Case 4 A 23 year old white male was referred because of a four month history of wax impacted in the right ear with subsequent infection of the canal Examination revealed a pedunculated bony growth attached antero superiorly to the bone of the right external canal superficial to the isthmus, with less than one third of the normal lumen remaining The hearing was normal despite a large plug of cerumen

The osteoma was removed under endotracheal anesthesia* A small sturdy attic hook was placed deep to the lesion A tap on a curved gouge the blade of which had been placed at the pedicle resulted in separation of the tumor It was delivered with the hook. There was no bleeding The tumor had been attached to the tympano squamous suture The cerumen plug was removed revealing a normal tympanic membrane Gelfoam was placed in the canal and removed in one day The canal healed within a week

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*Surgery performed by Colonel Edward J Whiteley

SUMMARY

An osteoma of the external auditory canal, although not common, is not extremely rare It must be differentiated from multiple exostoses, which are common These two lesions have been defined and discussed from the standpoint of symptomatology and treatment

An osteoma of the external auditory canal is always a surgical problem Four cases are reported

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AN ELECTROPHYSIOLOGIC PROCEDURE FOR DETERMINATION OF AUDITORY THRESHOLD IN CHILDREN *

FRANK B WITHROW, JR ,
and
ROBERT GOLDSTEIN,†
St Louis, Mo

Several electrophysiologic indices have been used in clinical audiometry in the attempt to determine auditory thresholds in adults and children who cannot or will not respond adequately during conventional audiometric tests which use conditioned behavioral responses The most commonly used electrophysiologic index is some change in electric characteristics of the skin in response to auditory stimulation (electrodermal response or EDR) This change, presumably mediated primarily by the activity of the sweat glands of the skin, can be demonstrated by alterations in impedance to flow of electric current or by alterations in electric potential between two points on the skin Another index employed clinically is a change in the pattern of electric activity of the brain in response to auditory stimulation (electroencephalic response, or EER)

The principal value of auditory tests which use EDR and EER in response to sound as indicators of "hearing" is the information which they can contribute beyond that to be derived from observing behavioral responses Consequently, it is desirable that judgment of a change in an electrodermogram, or an electroencephalogram, as a response to a particular auditory stimulus be independent of the tester's knowledge of the stimulus and of the patient's overt behavior during stimulation It is also desirable that threshold be estimated

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†Now Research Associate Department of Otolaryngology The Jewish Hospital of St Louis

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from the distribution of responses on the basis of predetermined criteria, just as it is in the more conventional audiometric procedures

The procedure developed by Stewart[13] and elaborated clinically by Doerfler and McClure[9] satisfy the conditions mentioned in the previous paragraph Their procedure, however, requires some prior knowledge of a patient's auditory sensitivity in order, *1* to find a level at which a stimulus is definitely audible for a preliminary conditioning period, and *2* to establish a limited range of intensities within which their auditory stimuli can be randomly ordered Consequently, Doerfler and McClure did not determine thresholds independent of any knowledge of behavioral responses, they confirmed that threshold lay within a range previously established by behavioral responses

Preliminary determination of an approximate threshold is usually difficult with the particular adults for whom electrophysiologic tests are most necessary It is even more difficult with very young children, and with children who are mentally retarded, emotionally disturbed, or aphasic.

The purpose of this paper is to describe another procedure for determination of auditory thresholds using both EDR and EER as indicators of "hearing," and to report results of attempts to use this procedure to assess the hearing of some children with auditory disorders

SUBJECTS

The subjects for this study were drawn from the children enrolled in full-time classes at Central Institute for the Deaf (CID) These children represent a calibrated sample, in a sense, because their hearing has been evaluated yearly since their enrollment at CID

Apparatus *

The apparatus used in this study was described by Charan and Goldstein[2] The stimulating apparatus consisted of an audiometer and a device for applying electric shock Sound was delivered monaurally either through earphones held in place by a headband, or through hearing-aid type earphones held in place in the ear canal with the children's own earmold If the child did not have his own earmold, a stock-mold was used, and it was taped in place to minimize acoustic leaks and to prevent its falling out of the canal It is preferable to use the hearing-aid type earphone in the EER-Audio portion (to be described) during which the child is asleep These smaller earphones, without a headband, are less likely than the larger earphones, *1* to interfere with the comfort of the child's head during sleep, *2* to interfere with the EEG electrodes attached to the child's scalp, and *3* to loosen and to allow acoustic leaks

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*The basic apparatus was a gift of the Children s Research Foundation St. Louis Mo

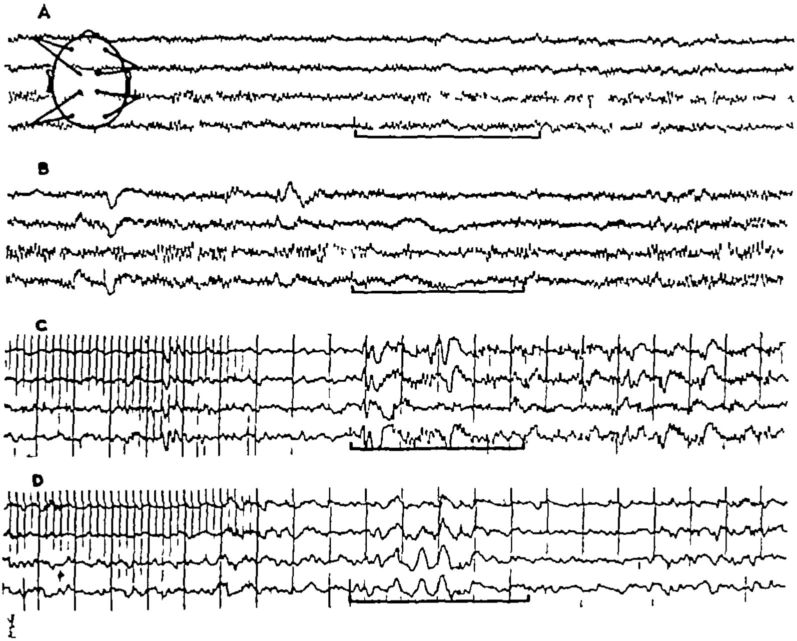


Fig 1 Sample electroencephalograms from the record of subject D during his EER-Audio The line under each strip indicates the duration of the auditory stimulus (approx. 5 sec) A and B Early stages of test child awake C and D child asleep Note clear electroencephalic responses in B C and D

The recording apparatus was a Grass four-channel electroencephalograph The electroencephalogram (EEG) was recorded by conventional procedures[6] The usual electrode placements were varied, however, according to a suggestion by Derbyshire,[3] so that the parietal lead was placed slightly posteriorly and the temporal lead was placed in a position in front of the usual parietal location The central leads from both sides were, therefore, bunched closely together near the top of the head Fig 1 shows the placement of the electrodes as well as a sample of the kind of recordings obtained from them The electrodes were attached to the head on portions of the scalp previously cleaned with alcohol Bentonite paste[6] insured satisfactory contact between the electrode and the scalp The electrodes were held in place with adhesive tape

The electrodermogram (EDG) was recorded on one channel of the electroencephalograph This method of recording has been described by Mays,[10] and by Goldstein, Ludwig and Naunton[9] In the present study, recording electrodes were taped to the tips of two fingers of the left hand The shock electrodes were attached to the calf of the left leg

PROCEDURE

EER-Audio[8]

The EER-Audio is performed when a child is asleep It is desirable that the children be tested in the evening or during regular nap-time, so that advantage can be taken of natural sleep whenever possible When a child does not go to sleep naturally, he can be lightly sedated The children in this study were given Seconal or Nembutal orally, under a neurologist's supervision

The test consists of 96 stimulus-conditions divided into six similar series of 16 A sample series is shown in Fig 2 Six different series are used to prevent inadvertent memorization of the sequence of stimuli in any series The order in which the six series are presented to any child is also randomized The stimuli are tones of 500 c p s or 2000 c p s with a duration of five seconds Each frequency is presented at three different intensities corresponding to the audiometric levels of 10, 50 or 90 db hearing-loss If his general behavior indicates that a child has normal or nearly normal auditory sensitivity, the range of intensities can be restricted to 10, 40 and 70 db hearing-loss If there is any doubt whatsoever, the broader range of 10, 50 and 90 db hearing-loss is used

The combination of two frequencies and three intensities in both ears makes a total of 12 stimuli Randomly scattered among these 12 stimuli are four control-intervals, *i e*, four times a stimulus-mark is recorded on the electroencephalogram when no auditory stimulus is presented to the child A number corresponding to the order of the stimulus or control in the pre-arranged schedule is placed by each stimulus-mark A minimum of 25 seconds is allowed to elapse between stimuli It is not always possible to complete all six series When a child awakes and will not go back to sleep or relax quietly, the test is discontinued

No	Ear	Frequency (in c p s)	Hearing-Loss (db)
1	R	2000	10
2	L	2000	90
3	R	2000	90
4	L	2000	10
5	L	500	90
6		CONTROL	
7	L	500	10
8	L	500	50
9	L	2000	50
10		CONTROL	
11	R	500	90
12		CONTROL	
13	R	2000	50
14	R	500	10
15		CONTROL	
16	R	500	50

Fig 2 One of the series of stimuli used in the EER-Audio The other *five series have identical stimuli but in different sequences*

The records are not analyzed until after the test is completed

EDR-Audio [8]

The EDR-Audio is performed when the child is awake, either in the morning while he is alert, or in the afternoon after he has napped

This test, like the EER-Audio, consists of 96 stimuli, divided into six similar random series of 16 stimuli, and the stimuli are 500 c p s or 2000 c p s tones of five seconds duration (see Fig 3) Each frequency is presented at four different intensities corresponding to the audiometric levels 20, 40, 60 and 80 db hearing-loss Two frequencies and four intensities in both ears make a total of 16 stimuli for each series It is not necessary to use controls in the EDR-Audio because of the infrequency of random changes with the appropriate latency, time-course, and amplitude, which may be mistaken for responses to auditory stimuli

No	Ear	Frequency (in c p s)	Hearing-Loss (db)	Shock
1	L	500	20	
2	L	500	40	
3	R	2000	80	+
4	R	500	80	
5	R	2000	60	+
6	R	500	40	+
7	L	2000	20	+
8	R	2000	40	
9	L	2000	40	+
10	L	500	60	
11	R	500	60	+
12	L	2000	80	+
13	R	2000	20	
14	L	2000	60	
15	L	500	80	
16	R	500	20	+

Fig 3 One of the series of stimuli used in the EDR-Audio The other five series have identical stimuli but in different sequences

One-half of the 16 stimuli are followed by annoying electric shocks, regardless of the intensity of the auditory stimulus Because it is not required that shocks follow tones which are unquestionably audible, there is no need to have prior knowledge of an approximate hearing-loss We do not have certain knowledge as to what effect the use of shocks with inaudible tones will have on conditioning or responsiveness in general We have had some experience with adults, however, which indicates that shocks not preceded by audible tones do not depress responsiveness appreciably

As in the EER-Audio, only a number is placed by the stimulus-mark corresponding to the order of the stimulus in the pre-arranged schedule The records are analyzed after the test is finished

The EER-Audio is usually administered first, because the test involves no discomfort for the child, and he is not reluctant to return for the EDR-Audio Generally, it is more difficult to secure the cooperation of a child for the EER-Audio after he has been subjected to the shocks in the EDR-Audio

ANALYSIS OF THE RECORDS

The records are analyzed after the electrophysiologic tests are completed The only marks on the electroencephalograms and electrodermograms other than the tracings themselves are, *1* the various stimulus-marks, and *2* a number alongside of each mark corresponding to the order of the tone or control in the pre-arranged schedule The tester can note in a separate protocol the overt behavior of a child in response to a stimulus Judgments of responses to all 96 stimuli, or controls, are made before referring to the schedule

EER-Audio

Judgment of the presence of an electroencephalic response to a tone depends solely on how much the EEG pattern in or following the five seconds during which the tone is presented differs from the preceding pattern Derbyshire and his co-workers[4] have described the kinds of changes which can occur in response to a tone Fig 1 shows samples of electroencephalic responses from one of the children in this study (Subject D)

Although not all responses can be judged with equal certainty, a simple "yes" or "no" decision is made for each stimulus Responses to the 96 stimuli, or controls, are tabulated according to the scheme shown in Figs 4-10

EDR-Audio

Judgment of the presence of an electrodermal response to a tone depends primarily on the latency of a change in the impedance or potential of the skin following the onset of the tone The average latency is very close to 2 1 seconds Changes with latencies less than 1 5 seconds, or greater than 3 0 seconds, are disregarded unless a child consistently responds outside this range Changes of impedance or potential within this period usually are larger than the random changes, and usually reach maximum in a shorter time than do the random changes Responses to the 96 stimuli are tabulated in the same way as described for the EER-Audio

ESTIMATION OF THRESHOLD OR HEARING-LOSS

In a plot of behavioral responses as a function of intensity elicited by conventional audiometric procedures, one ordinarily finds a point of zero responses, a point of 100 per cent responses, and a sigmoid curve describing the locus of the intermediate points The 50 per cent point is usually chosen as threshold

TABLE I CRITERIA FOR ESTIMATION OF THRESHOLD

Number of false-positives in 24 control-intervals	Number of responses to six stimuli to be significantly* more than false-positives
0	2
1	2
2	3
3	3
4	4
5	4
6	4
7	5
8	5

*5 per cent level of a one-tailed distribution

The curve describing the frequency of electrophysiologic responses as a function of the intensity of the auditory stimulus usually does not have a zero point or a 100 per cent point, and the locus of the intermediate points is not certain A practical zero can be established for each individual, however, from the relative number of false-positives in the control-intervals The false-positives may be the result of faulty judgment during analysis of the records, or the result of an actual response to some extraneous stimulus Experience has shown that the number of false-positives in the EDR-

Audio is small, thus, practical zero is not very different from true zero In the EER-Audio, the percentage of false-positives is somewhat larger

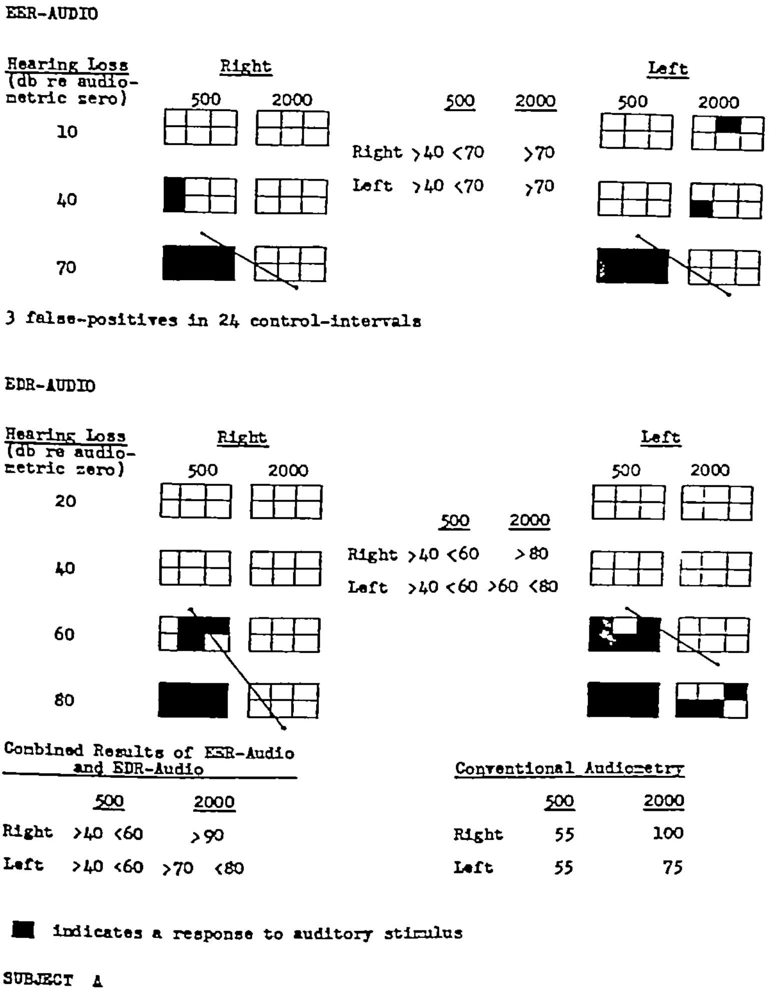
Statistical calculations[13] provide a criterion for determining the stimulus-level at which significantly more responses than false-positives occur (see Table I) This criterion is based on the 5 per cent point for a one-tailed test The weakest stimulus-level at which this criterion is met is regarded as (or above) the subject's threshold

Because there are no control-intervals in the EDR-Audio, estimates of threshold are made conservatively One can assume that there would have been a maximum of two or three false-positives if 24 control-intervals had been used Thus, in the EDR-Audio there must be at least three responses to six stimuli at a given level to indicate "hearing" at that level

The following section describes the results of attempts to confirm the above criteria for threshold For this purpose we have chosen some children from the full-time classes at Central Institute for the Deaf, who have been tested repeatedly by conventional audiometry, and have shown the same audiogram over a period of several years We shall also describe the attempts to apply these criteria to the determination of hearing-losses in some children for whom conventional procedures produced inadequate or conflicting results Although the audiometric records were on file, we had no knowledge of the audiograms of any of the children before they were tested The results of the electrophysiologic and the conventional tests were compared only after the records from the electrophysiologic tests had been analyzed

RESULTS

The following examples will show how the application of the above criterion served to determine the hearing-loss within ±10 db of thresholds previously determined by conventional audiometry


EER-AUDIO
Hearing Loss (db re audiometric zero)
Right
Left
500
2000
10
40
70

	500	2000
Right	>40 <70	>70
Left	>40 <70	>70

3 false-positives in 24 control-intervals

EDR-AUDIO
Hearing Loss (db re audiometric zero)
Right
Left
500
2000
20
40
60
80

	500	2000
Right	>40 <60	>80
Left	>40 <60	>60 <80

Combined Results of EER-Audio and EDR-Audio

	500	2000
Right	>40 <60	>90
Left	>40 <60	>70 <80

Conventional Audiometry

	500	2000
Right	55	100
Left	55	75

■ indicates a response to auditory stimulus

SUBJECT A

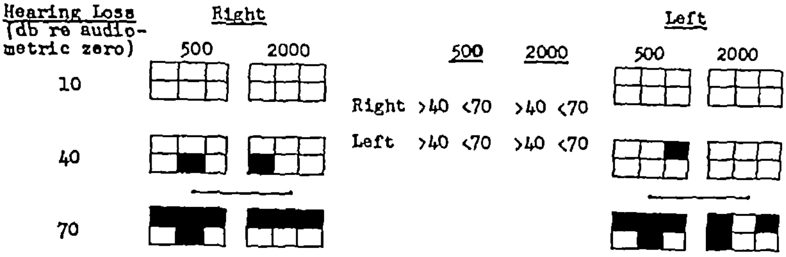
Fig 4 Plot of responses from the EER-Audio and EDP-Audio for Subject A.

A 13 years old (see Fig 4)

Because a relatively small hearing-loss was suspected on the basis of general behavior, the hearing-losses of 10, 40 and 70 db (re audiometric zero) were used in the EER-Audio instead of 10, 50 and 90 db ordinarily recommended

There was not sufficient intensity at 70 db hearing-loss

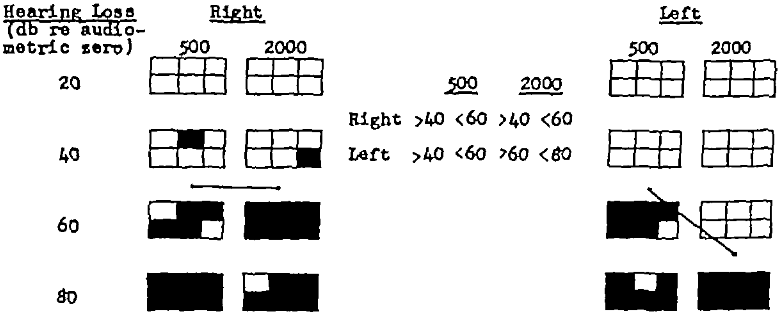
EER-AUDIO



	500	2000
Right	>40 <70	>40 <70
Left	>40 <70	>40 <70

1 false-positive in 24 control-intervals

EDR-AUDIO



	500	2000
Right	>40 <60	>40 <60
Left	>40 <60	>60 <80

Combined Results of EER-Audio and EDR-Audio

	500	2000
Right	>40 <60	>40 <60
Left	>40 <60	>70 <80

Conventional Audiometry

	500	2000
Right	50	50
Left	50	55

■ indicates a response to auditory stimulus

SUBJECT B

Fig 5 Plot of responses from the EER-Audio and EDR-Audio for Subject B

to elicit three responses to 2000 c p s delivered to either ear The responses to 500 c p s were sufficiently frequent so that on the basis of the EER-Audio alone, this child's hearing-losses were

	500	2000
Right	>40 <70 db	>70 db
Left	>40 <70 db	>70 db

According to the EDR-Audio his hearing-losses were

	500	2000
Right	>40 <60 db	>80 db
Left	>40 <60 db	>60 <80 db

The combined results of EER-Audio and EDR-Audio indicated the hearing-losses to be

	500	2000
Right	>40 <60 (55) db	>80 (>100) db
Left	>40 <60 (55) db	>70 <80 (75) db

The numbers in parentheses are the hearing-losses determined by conventional audiometry by other examiners with other equipment

B 11½ years old (see Fig 5)

Again, because only a moderate hear-loss was suspected, intensities corresponding to 10, 40 and 70 db hearing-loss were used On the basis of our criterion, the child's hearing-losses according to the EER-Audio were

	500	2000
Right	>40 <70 db	>40 <70 db
Left	>40 <70 db	>40 <70 db

According to the EDR-Audio the hearing-losses were

	500	2000
Right	>40 <60 db	>40 <60 db
Left	>40 <60 db	>60 <80 db

The combined results of the EER-Audio and EDR-Audio indicated the hearing-losses to be

	500	2000
Right	>40 <60 (50) db	>40 <60 (50) db
Left	>40 <60 (50) db	>60 <70 (55) db

The numbers in parentheses again represent the hearing-losses from conventional audiometry performed by other examiners with other equipment The discrepancy (approximately 10 db) between the thresholds determined electrophysiologically and psychophysically for 2000 c p s in the left ear is not appreciably more than can be expected from differences in calibration between the two audiometers or from test-retest reliability

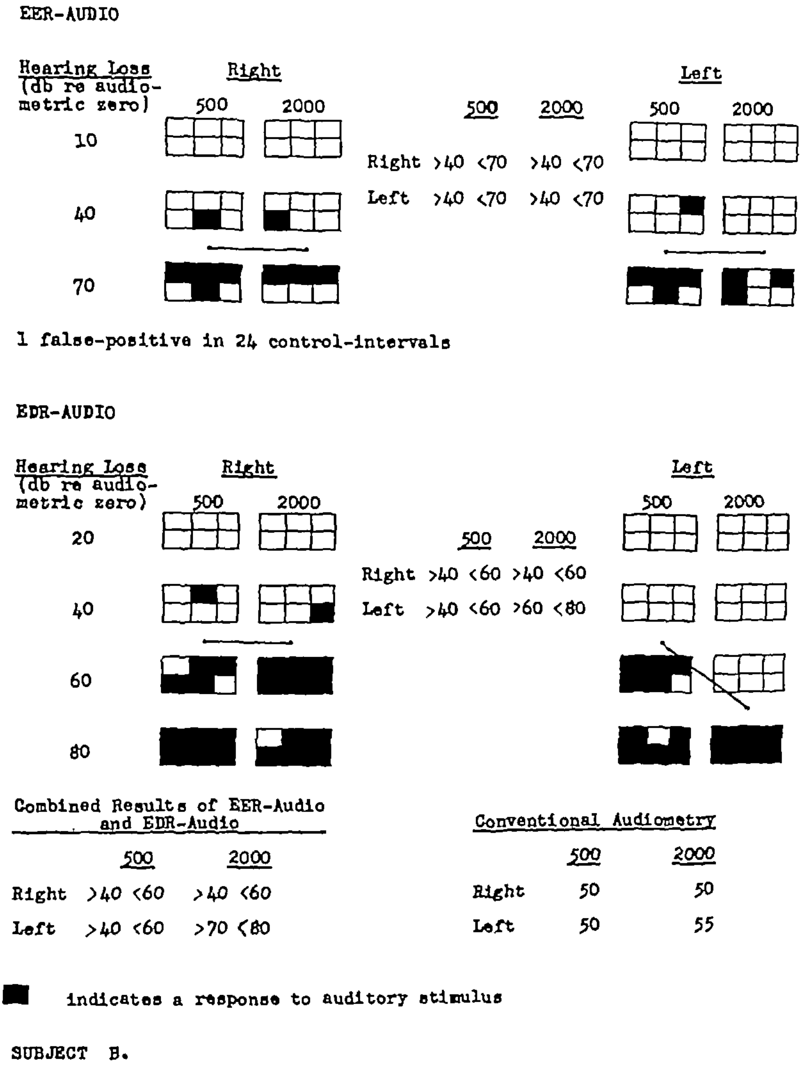


Fig 6 Plot of responses from the EER-Audio and EDR-Audio for Subject B

to elicit three responses to 2000 c p s delivered to either ear The responses to 500 c p s were sufficiently frequent so that on the basis of the EER-Audio alone, this child's hearing-losses were

	500	2000
Right	>40 <70 db	>70 db
Left	>40 <70 db	>70 db

According to the EDR-Audio his hearing-losses were

	500	2000
Right	>40 <60 db	>80 db
Left	>40 <60 db	>60 <80 db

The combined results of EER-Audio and EDR-Audio indicated the hearing-losses to be

	500	2000
Right	>40 <60 (55) db	>80 (>100) db
Left	>40 <60 (55) db	>70 <80 (75) db

The numbers in parentheses are the hearing-losses determined by conventional audiometry by other examiners with other equipment

B 11½ years old (see Fig 5)

Again, because only a moderate hear-loss was suspected, intensities corresponding to 10, 40 and 70 db hearing-loss were used On the basis of our criterion, the child's hearing-losses according to the EER-Audio were

	500	2000
Right	>40 <70 db	>40 <70 db
Left	>40 <70 db	>40 <70 db

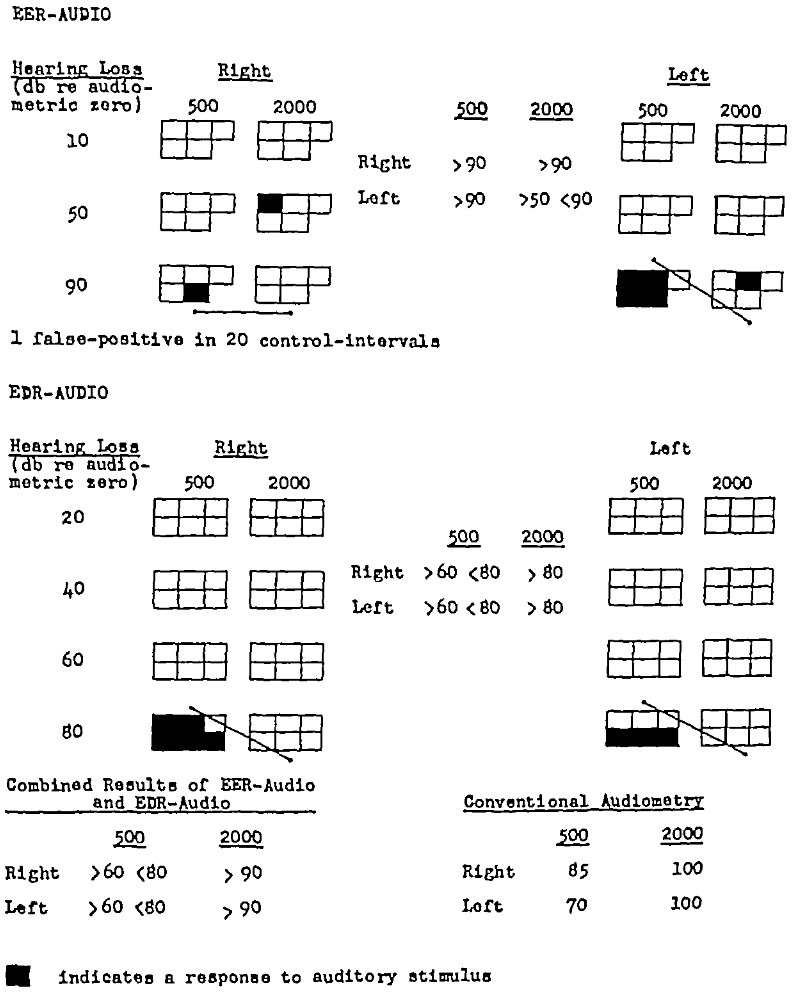
According to the EDR-Audio the hearing-losses were

	500	2000
Right	>40 <60 db	>40 <60 db
Left	>40 <60 db	>60 <80 db

The combined results of the EER-Audio and EDR-Audio indicated the hearing-losses to be

	500	2000
Right	>40 <60 (50) db	>40 <60 (50) db
Left	>40 <60 (50) db	>60 <70 (55) db

The numbers in parentheses again represent the hearing-losses from conventional audiometry performed by other examiners with other equipment The discrepancy (approximately 10 db) between the thresholds determined electrophysiologically and psychophysically for 2000 c p s in the left ear is not appreciably more than can be expected from differences in calibration between the two audiometers or from test-retest reliability



EER-AUDIO

	500	2000
Right	>90	>90
Left	>90	>50 <90

EDR-AUDIO

	500	2000
Right	>60 <80	> 80
Left	>60 < 80	> 80

Combined Results of EER-Audio and EDR-Audio

	500	2000
Right	>60 <80	> 90
Left	>60 <80	> 90

Conventional Audiometry

	500	2000
Right	85	100
Left	70	100

Fig 6 Plot of responses from the EER-Audio and EDR-Audio for Subject C

C 7½ years old (see Fig 6)

Only five instead of the usual six series were given in the EER-Audio, because this child awoke before the end of her test On the basis of three responses to five stimuli as the criterion for "hearing," this child's hearing-losses were

	500	2000
Right - -	>90 db	>90 db
Left -	>50 <90 db	>90 db

The six series of the EDR-Audio were completed The hearing-losses according to this test were

	500	2000
Right	>60 <80 db	>80 db
Left	>60 <80 db	>80 db

The EDR-Audio showed "hearing" in the right ear for 500 c p s at the 90 db level, the EER-Audio did not

The following are the hearing-losses based on both the EER-Audio and EDR-Audio combined, along with the findings from conventional audiometry (in parenthesis)

	500	2000
Right	>60 <80 (85) db	>90 (>100) db
Left	>60 <80 (70) db	>90 (100) db

The discrepancy (approximately 10 db) between the findings determined electrophysiologically and psychophysically for 500 c p s in the right ear is not appreciably greater than differences in calibration or test-retest reliability

D 10 years old (see Fig 7)

On the basis of our criteria, this child's hearing-losses according to the EER-Audio were

	500	2000
Right	>10 <50 db	>50 <90 db
Left	>50 <90 db	>90 db

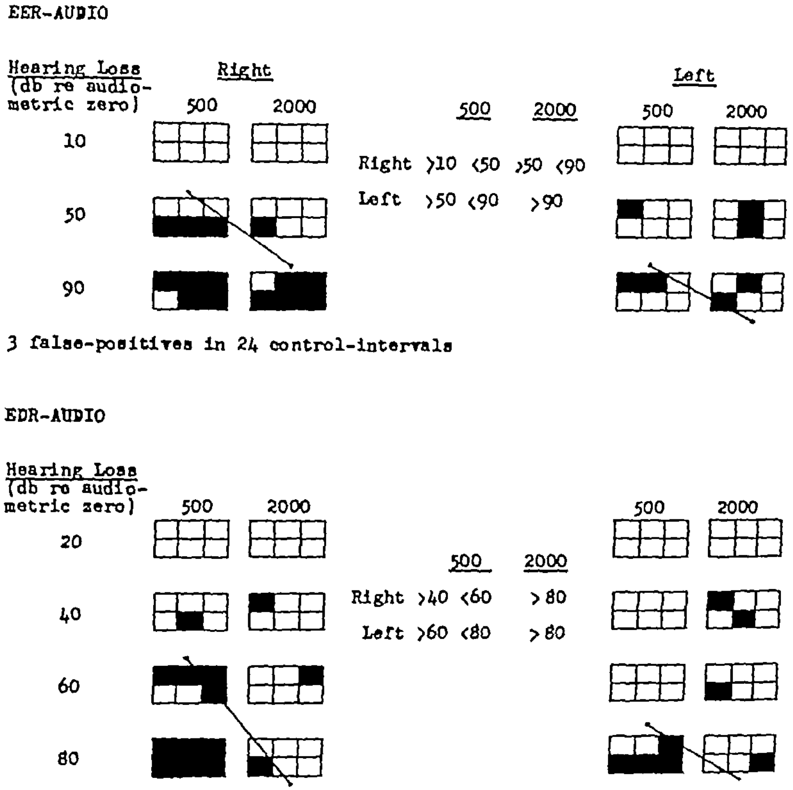
According to the EDR-Audio his hearing-losses were

	500	2000
Right	>40 <60 db	>80 db
Left	>60 <80 db	>80 db

The hearing-losses based on both tests and the results of conventional audiometry (in parentheses) are as follows

	500	2000
Right	>40 <60 (35) db	>80 <90 (95) db
Left	>60 <80 (75) db	>90 (>100) db

There are two minor discrepancies (approximately 10 db) between electrophysiologically and psychophysically determined thresholds for 500 c p s and 2000 c p s in the right ear As in the cases previously cited, these discrepancies can



Combined Results of EER-Audio and EDR-Audio

	500	2000
Right	> 40 < 50	> 80 < 90
Left	> 60 < 80	> 90

Conventional Audiometry

	500	2000
Right	45	95
Left	75	100

■ indicates a response to auditory stimulus

SUBJECT D

Fig. 7 Plot of responses from the EER-Audio and EDR-Audio for Subject D

be accounted for by differences in calibration or by test-retest reliability

The preceding "calibrated" examples not only confirm a criterion for threshold derived from theoretical considerations, but also allow an estimation of the frequency with which judgments of false-positives are made In the EER-

Audio of each of the preceding instances, there were 3 in 24, 1 in 24, 1 in 20, and 3 in 24, respectively, false-positives in the control-intervals If stimuli below each child's threshold are considered as controls, a similar frequency of false-positives is noted 4 in 60, 3 in 48, 2 in 60, and 6 in 48, respectively On the basis of these four examples, one may expect anywhere from 4 to 13 per cent false-positives with the EER-Audio

In the EDR-Audio, these same children gave the following number of false-positives to stimuli below their thresholds 0 in 66, 2 in 48, 2 in 84, and 8 in 78, respectively On the basis of these four children, an observer should expect to judge from 0 per cent to 10 per cent false-positives in the EDR-Audio This is comparable to about 2 per cent false-positives found in another study on normal adults[12]

The data reported here is typical of that found in successful tests with cooperative patients, but it should be emphasized that the EER-Audio and EDR-Audio are not always so successful as in the four cases just described

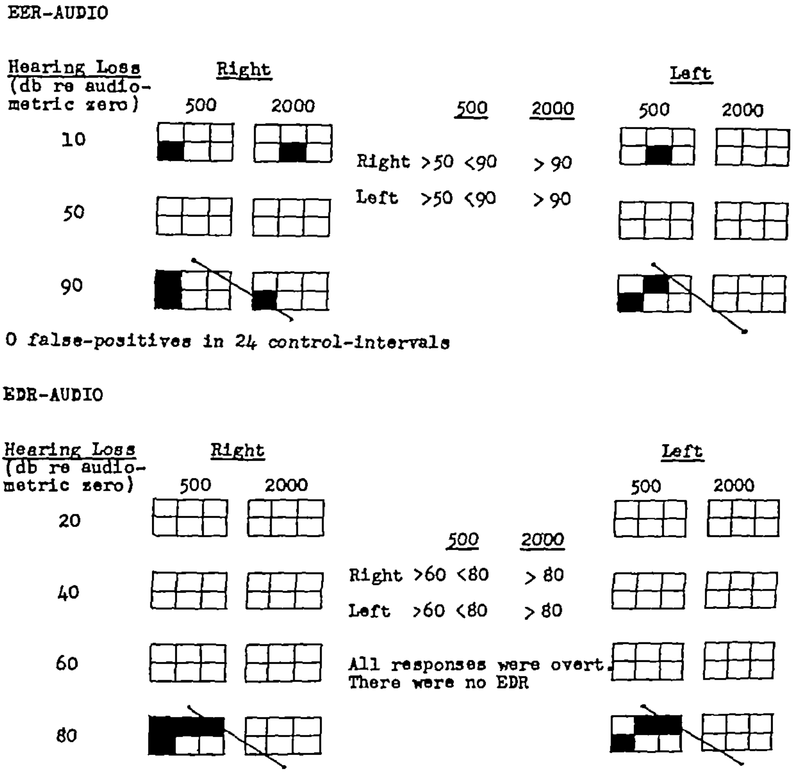
In the following examples, varying degrees of success were achieved, and certain modifications in the criterion for threshold were made in order to salvage some usable information from the tests

E 8 years old (see Fig 8)

Because there were no false-positives in the 24 control-intervals of the EER-Audio, only two responses to six stimuli were required to establish threshold On this basis the hearing-losses for this child were

	500	2000
Right	>50 <90 db	>90 db
Left	>50 <90 db	>90 db

In the EDR-Audio there were no definite EDRs to any of the 96 stimuli What is plotted in the analysis of the EDR-Audio in Fig 8 were the only definite overt responses observed during the test On the basis of these overt responses, the hearing-losses were



	500	2000
Right	>50 <90	> 90
Left	>50 <90	> 90

0 false-positives in 24 control-intervals

	500	2000
Right	>60 <80	> 80
Left	>60 <80	> 80

All responses were overt. There were no EDR

Combined Results of EER-Audio and EDR-Audio

	500	2000
Right	> 60 <80	> 90
Left	> 60 <80	> 90

Conventional Audiometry

	500	2000
Right	70	100
Left	75	95

■ indicates a response to auditory stimulus

SUBJECT E

Fig 8 Plot of responses from the EER-Audio and EDR-Audio for Subject E

	500	2000
Right	>60 <80 db	>80 db
Left	>60 <80 db	>80 db

On the basis of the evidence from both tests, the hearing-losses were estimated to be

	500	2000
Right	>60 <80 db	>90 db
Left	>60 <80 db	>90 db

Because the range of hearing-losses from the EER-Audio coincided with the range of hearing-losses estimated from overt responses in the EDR-Audio, the hearing-losses could be reported with considerable certainty. The findings allowed us to resolve a difference in educational recommendations based partially on differing pure-tone audiograms. Initially it was believed that this child had only a mild hearing-loss, and it was recommended that he be educated as an aphasic child. His educational development, however, was like that of a deaf child, and later audiograms determined by conventional audiometry, though they had been reported with qualifications, were confirmed by the above estimate of hearing-loss from the electrophysiologic tests.

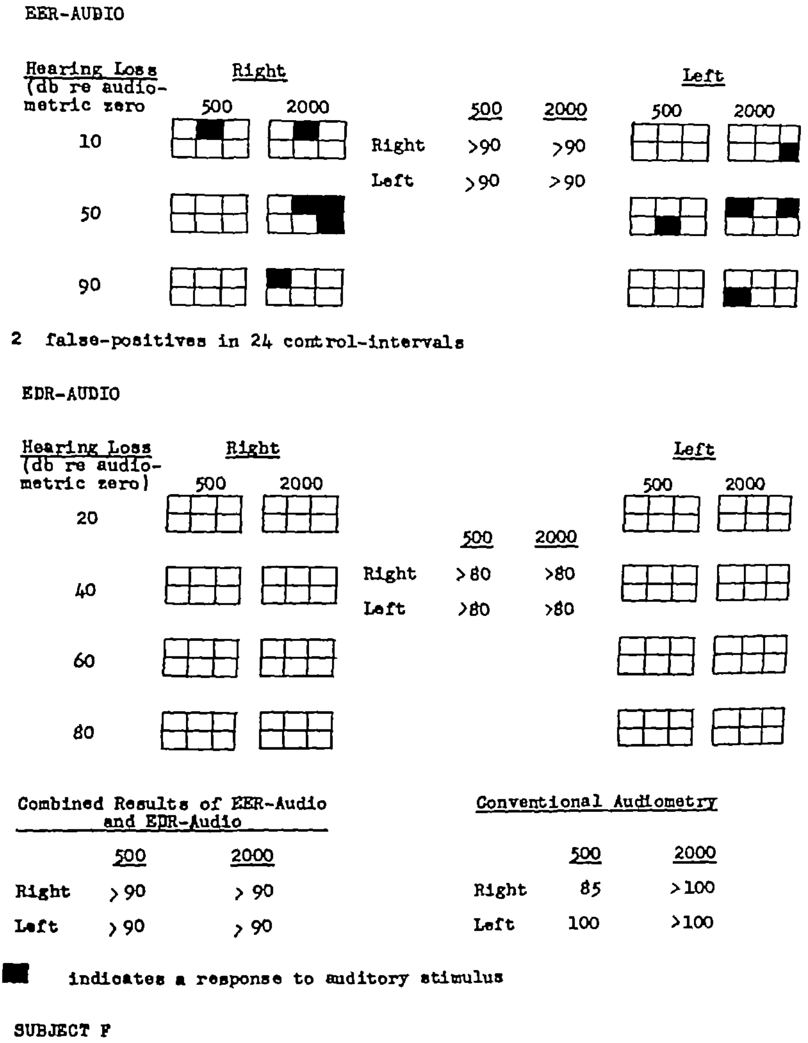
F. 8 years old (see Fig. 9)

In the EER-Audio there were at least three responses to six stimuli only for 2000 c.p.s. in the right ear, at 50 db hearing-loss; there was only one response at 90 db hearing-loss. To the six stimuli of 2000 c.p.s. at 50 db hearing-loss in the left ear, there were two responses; at all other frequencies and intensities there were one or no responses. One might have assumed from the pattern of responses that the hearing-losses were

	500	2000
Right	>90 db	>10 <50 db
Left	>90 db	>10 <50 db

Such a pattern, however, is rarely, if ever, seen clinically and in this instance was not consistent with the child's usual reactions to sound. In addition, the total of 11 responses to all 96 stimuli is not significantly more than the two false-positives in the 24 control-intervals. Our assumption, therefore, was that the child's hearing-loss was greater than 90 db for 500 c.p.s. and 2000 c.p.s. in both ears.

In the EDR-Audio there were no responses to the 96 stimuli used either because this child was particularly difficult to condition, or because the sound was not sufficiently intense to elicit responses. We tested these possibilities at the end of the regular EDR-Audio by presenting sounds exceeding the



EER-AUDIO

	500	2000
Right	>90	>90
Left	>90	>90

EDR-AUDIO

	500	2000
Right	>80	>80
Left	>80	>80

Combined Results of EER-Audio and EDR-Audio

	500	2000
Right	>90	>90
Left	>90	>90

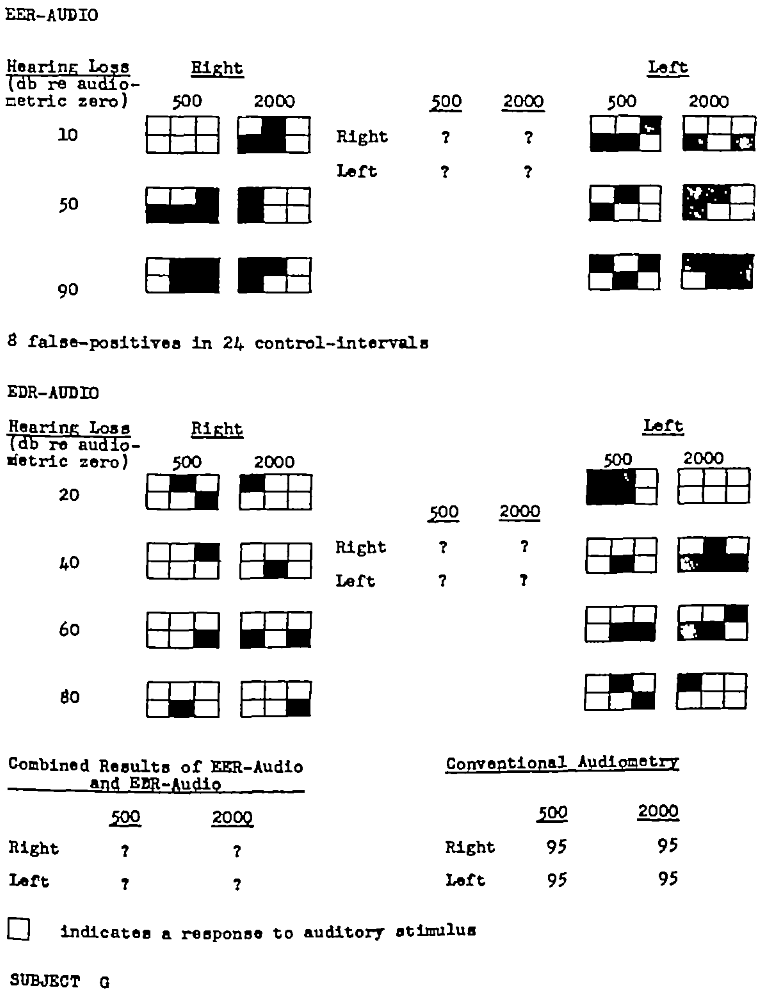
Conventional Audiometry

	500	2000
Right	85	>100
Left	100	>100

Fig 9 Plot of responses from the EER-Audio and EDR-Audio for Subject F

intensity for 90 db hearing-loss. The child consistently gave EDRs to these latter sounds.

The lack of electrophysiologic responses below the 90 db hearing-loss was in accord with his limited reaction to sound from the group hearing-aid in his classroom. The findings were also in accord with conventional audiometry (reported with limited certainty), and helped to resolve a difference in



EER-AUDIO

	500	2000
Right	?	?
Left	?	?

EDR-AUDIO

	500	2000
Right	?	?
Left	?	?

Combined Results of EER-Audio and EDR-Audio

	500	2000
Right	?	?
Left	?	?

Conventional Audiometry

	500	2000
Right	95	95
Left	95	95

Fig 10 Plot of responses from the EER-Audio and EDR-Audio for Subject G

educational recommendations similar to the previous case (Case E)

G 6 years old (see Fig 10)

From the distribution of responses shown in Fig 10, it is obvious that a hearing-loss based on the EER-Audio or EDR-Audio would have questionable validity In addition, the occurrence of a false-positive for every three controls in the EER-Audio requires five responses to six stimuli as evidence for hearing at a given stimulus-level. This criterion is met only at the 90 db. level for 2000 c.p.s. in the left ear.

There are slightly more EER and EDR to stimuli in the left ear than in the right. In the EER-Audio there is a small tendency for more responses to the more intense sounds than to the weaker sounds. Neither trend appears significant.

Conventional audiometry was relatively unsuccessful, and although the EER-Audio can be considered partially confirmative of the hearing-losses that were estimated, attempts to measure hearing-loss by electrophysiologic techniques were actually unsuccessful.

DISCUSSION

The procedures outlined in this paper appear to satisfy some of the requirements for objectivity: the response-mechanism is not dependent upon the active cooperation of the subject, no special variation in procedure is required for each patient (although the intensity range can be compressed if desired), and hearing-losses can be estimated on the basis of a previously established criterion. The electrophysiologic tests are also independent in that they require no prior knowledge of a patient's auditory behavior and no knowledge of a patient's overt behavior during the test.

The objectivity and independence of the test does not compel the tester to ignore the overt behavior of the patient. This behavior can be recorded in a separate protocol (cf. example E in section on results) and then be related to the results of the electrophysiologic test. Likewise, the results of other attempts to measure hearing-losses through behavioral responses can be compared with the results of the electrophysiologic tests. We endorse the view[1, 11, 14] that electrophysiologic tests should supplement, not supplant, the conventional methods of measuring hearing-loss.

On the basis of our own clinical and experimental experience, we believe that many of the EDR we elicit are unconditioned, certainly all of the EER during sleep are unconditioned We believe that we are able to maintain a relatively high rate of responses because of the variation in stimuli which is a consequence of the random schedule When the stimuli are varied with respect to frequency, intensity and ear, each stimulus tends to be somewhat novel and thus acts as an unconditioned stimulus

Because so little adaptation of the procedure is needed for each patient and because of the relative simplicity of the task of analysis, a tester need have little experience with electrophysiologic techniques to administer these tests successfully, providing that he has a good understanding of the general principles of clinical audiometry Audiologists with virtually no previous experience with either the EER-Audio or EDR-Audio have already used these techniques successfully in our clinics

The procedures described in this paper are not intended to be definitive or final, but rather to be a prototype for electrophysiologic procedures for determination of hearing-losses Since the preparation of this paper, we have already tried certain modifications in the procedures For instance, in the EDR-Audio we are testing the feasibility of using intensities corresponding to 20, 60 and 100 db hearing-loss instead of the 20, 40, 60 and 80 db presently used This change may serve to reduce the time of the test and make it more likely to elicit responses from profoundly deaf children

Much experimental work is needed to produce refinements that will insure more success with any particular procedure Such factors as the optimum duration of the stimulus and the optimum length of time between successive stimuli need to be investigated, as well as such technical aspects as control of the level of sleep, most satisfactory location of electrodes, and automatic analysis of records

The results we have obtained indicate that our procedures can be used practically Although we have presented results of our tests on children, there is no reason to believe that these tests could not work just as satisfactorily with adults

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necessary to stimulate the auditory nerve to make it deliver enough impulses to the central nervous system to initiate two particular kinds of responses The thresholds reported, therefore, probably represent the minimum strength of sound to which a child is organically capable of responding

When a child is tested by both the EER-Audio and EDR-Audio, there is a greater probability of obtaining a certain estimate of a small range (±10 db) within which the hearing-loss lies than when only one of the tests is given Nevertheless, when either test is successful, it is possible to obtain a range for the hearing-losses certain enough and narrow enough to give important support for making particular recommendations for special education

Each test has advantages and disadvantages affecting its clinical practicality and desirability The EER-Audio is less desirable than the EDR-Audio for the following reasons *1* Technically, the EER-Audio is more difficult to administer (control of sleep, multiplicity of wires, more channels for recording, etc) , *2* When a child is asleep during the EER-Audio, naturally it is impossible for him to display his normal overt responses to sound, *3* It is impractical to condition electroencephalic responses in a sleeping child, as one would condition electrodermal responses to sound in a child who is awake, *4* It is more difficult to discern electroencephalic responses in an electroencephalogram than it is to discern electrodermal responses in an electrodermogram

The EER-Audio has these advantages over the EDR-Audio *1* Because no conditioning is used with the EER-Audio, there is no disturbance of the child with electric shock or other annoying unconditioned stimulus, *2* During the EDR-Audio, most young children are restless, and they squirm, partially in boredom during a long and uninteresting (to them) test Very often they scream, kick and are generally disturbed because of the discomfort of the shock and because they are aware of the wires, phones, and the strange circumstances of the whole test-situation During the EER-Audio the children are asleep (usually before the application of electrodes) and thus are unaware of and unfrightened by the test, *3* Con-

In fact, we do use a modified form of the EDR-Audio for *confirmation* of hearing-losses in adults

Success of the EER-Audio and EDR-Audio, as outlined in this paper, does not appear to be dependent upon the particular kind of child or the nature of his auditory disorder In the examples presented in the previous section, subject C is the only one who can be classified as an uncomplicated deaf child Subjects A and D are aphasic children with hearing-losses Subject B has a hearing-loss, and his problem in communication is complicated by a low intellectual capacity Subjects E and F are considered deaf children, although they were referred for education with a diagnosis of some defect of the central nervous system which impeded normal development of language Both of these children have serious behavioral problems which complicate their auditory difficulties The child who was unsuccessfully tested (subject G) is classified educationally as aphasic, and has additional complications of a probable hearing-loss and emotional problems

It has been our experience that there is no discrepancy or, at most, a minor discrepancy between the hearing-losses determined by procedures requiring overt responses and the hearing-losses determined by electrophysiologic techniques when the results of both kinds of tests are reasonably clear Because of this agreement, we usually feel confident that clearly determined hearing-losses from the EER-Audio and EDR-Audio can be reported as representing a child's sensitivity to sound, even when the results of the more conventional techniques are too inconsistent to be corroborative Occasionally there is an appreciable discrepancy between the findings from the EER-Audio and the EDR-Audio In these instances, the EER-Audio usually indicates less hearing-loss

We have no clear understanding at present of the anatomic structures or of the physiologic processes involved in the electrophysiologic responses to sound Although a report may be given within ±10 db of the intensities believed to be a child's "threshold of hearing," the report does not tell us how the child ordinarily reacts to sound at or above his threshold The findings merely state how much intensity is necessary to stimulate the auditory nerve to make it deliver enough impulses to the central nervous system to initiate two particular kinds of responses The thresholds reported, therefore, probably represent the minimum strength of sound to which a child is organically capable of responding

When a child is tested by both the EER-Audio and EDR-Audio, there is a greater probability of obtaining a certain estimate of a small range (±10 db) within which the hearing-loss lies than when only one of the tests is given Nevertheless, when either test is successful, it is possible to obtain a range for the hearing-losses certain enough and narrow enough to give important support for making particular recommendations for special education

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sistent electrodermal responses are difficult to elicit in very young children[7] According to Derbyshire,[4] electroencephalic responses to sound do not seem to be limited by age, and this seems to be true in our experience as well

If only one test or the other were to be used for young children, we should favor the EER-Audio, primarily on the basis of the greater ease of handling of the children and because of the greater likelihood of eliciting responses Reliability and narrowing of the range in which the hearing-loss lies could be achieved by successive EER-Audios We suggest, however, that if it is at all feasible, both the EDR-Audio and EER-Audio be done on the same child

SUMMARY

In two separate tests, electroencephalic responses (child asleep) and electrodermal responses (child awake) to sound are used as indicators of "hearing" In both tests, tones of 500 c p s and 2000 c p s at different intensities are presented to either ear, according to a previously prepared, random schedule The stimulus-levels in the first test correspond to 10, 50 and 90 db hearing-loss, and in the second to 20, 40, 60 and 80 db hearing-loss The records are analyzed only after the tests have been completed and without knowledge, at the time of analysis, of the particular stimulus (or control) which corresponds to the ordinal number placed near each stimulus-mark The combined results of both tests can yield an estimate of hearing-loss within ±10 db of thresholds determined from behavioral responses Separately, either test yields less certain and precise estimates of hearing-loss

Acknowledgments The authors thank Dr James O'Leary and members of his staff of the Division of Neurology and Electroencephalography, Washington University School of Medicine, for their help with the EEG equipment and with the administration of the sedatives, Dr A J Derbyshire, Jr , Director of the EEG Department, Harper Hospital, Detroit, for his many helpful suggestions during the early stages of this study, and members of the Hearing Clinics and Research Department of Central Institute for the Deaf,

associated with a columella that is too short The reason for dividing them in this manner is because each type requires a different treatment when the use of the orthopedic septo-columellar suture is considered

The orthopedic suture should never be used in the Type I tip and is never indicated, providing the cartilaginous dorsum of the septum is lowered adequately at operation I think this is of primary importance and should be emphasized The orthopedic septo-columellar suture, on the other hand, is obligatory in Type II Unless it is used in every tip of Type II the result will be an unsatisfactory rhinoplasty, even in the hands of the experienced surgeon

TYPE I NASAL TIP

This is the commonly encountered nasal tip, the one most frequently operated upon It is the large oversized nose with a prominent nasal tip that possesses adequate projection When the cartilaginous dorsum is left too high in such a nose, the judgment of the surgeon is usually at fault, and is the initial mistake leading to a train of errors In order to create a straight profile at operation, the surgeon makes a second mistake by elevating the nasal tip to the level of the too high cartilaginous dorsum of the septum This he accomplishes by means of the orthopedic septo-columellar suture applied high on the septum and low on the columellar What is desirable is not an increase in the elevation of the nasal tip Instead, the cartilaginous dorsum of the septum should be lowered to the level of the nasal tip The technique for lowering the cartilaginous dorsum of the septum adequately has been described in a previous article[3] The nasal tip, by means of this technique, stands up in its natural position unassisted and unsupported by artificial means Under these conditions, it will retain its position postoperatively Certainly, overcorrection of the tip on the septum by means of the orthopedic septo-columellar suture is contraindicated and should be condemned in every case of Type I tip Light catgut sutures between the vestibular skin of the columella and nasal septum will suffice in approximating the columella to the septum

EVALUATION OF THE ORTHOPEDIC SEPTO-COLUMELLAR SUTURE IN RHINOPLASTY

GUSTAVE B. FRED, M.D.,

Boston, Mass.

The beginner in rhinoplasty is usually taught that essentially all nasal tips fall postoperatively after the septo-columellar sutures are removed and that it is, therefore, necessary to overcorrect or elevate the nasal tip on the septum in every case. In order to effect this, he raises the tip by means of the so-called orthopedic septo-columellar suture applied high on the septum and low on the columella, with the hope that the tip will eventually come down just right and that the postoperative esthetic effect will result in an attractive nose. In many cases it does just that—it comes down just right. Frequently, however, the tip falls down too much, resulting in a nose that is too long, a tip too round, and the cartilaginous dorsum of the septum too high; and there are rare occasions when the tip for some unaccountable reason remains too high. Too much, therefore, is left to chance, and under these conditions there is no control over the amount of pull and direction that the tip will take.

The teaching is fallacious. There are times when the orthopedic septo-columellar suture is definitely contraindicated, and under no circumstances should be used. At other times it is obligatory and must be employed, otherwise failure will surely result. All rhinoplasty surgeons agree that the orthopedic septo-columellar suture should not be used routinely in rhinoplasty.

When the feasibility of using the orthopedic suture is contemplated, it is helpful to divide nasal tips into two types: Type I, which possesses adequate projection with a sufficiently long columella; and Type II tip with inadequate projection,

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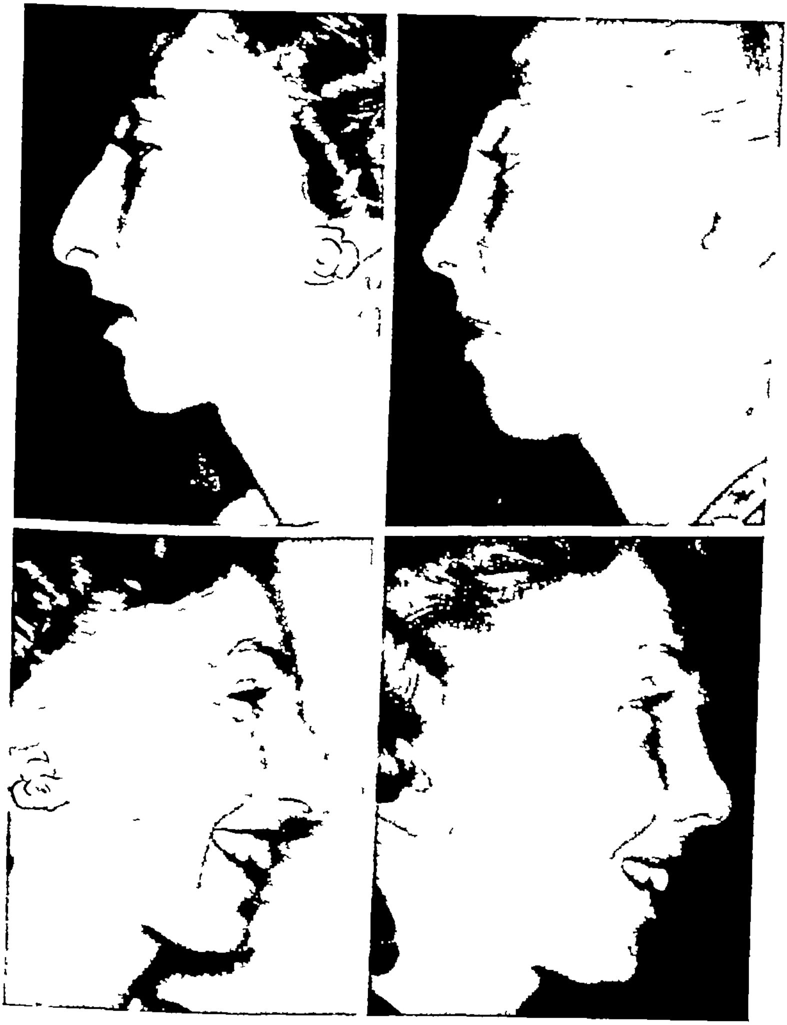

Fig 2 Type II nasal tip—Inadequate tip projection associated with a short columella The orthopedic septo-columella suture is indicated in every case of Type II and should be used in conjunction with invagination and severing the depressor septi nasi muscle in the columella

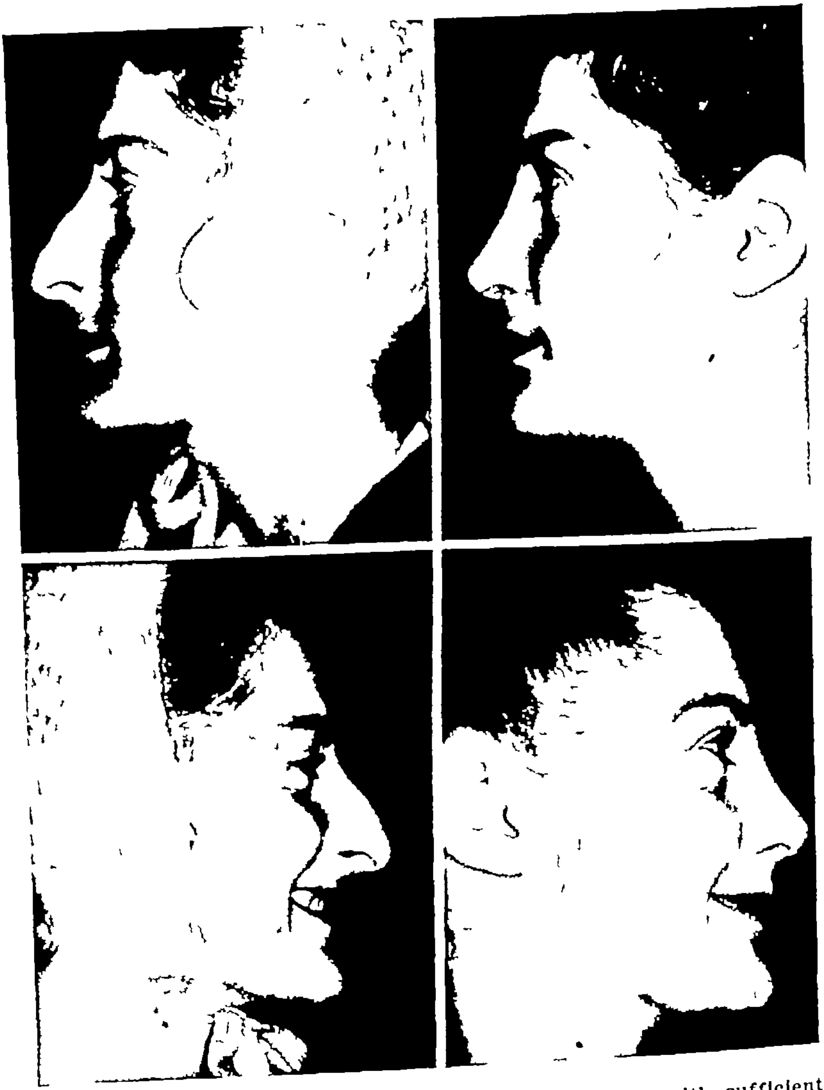

Fig 1 Type I nasal tip—Adequate projection of tip with sufficiently long columella The orthopedic septo-columella suture is never indicated in Type I nasal tip

orthopedic septo-columellar suture is obligatory in every case of Type II In order to keep the tip in the elevated position, overcorrection must be combined with invagination,[1] and severing all the fibers of the depressor septi nasi muscle[2] in the columella to insure the permanent stability of the elevated tip

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TYPE II

The Type II nasal tip is totally different and far more difficult to correct than Type I Bold, heroic treatment is obligatory Overcorrection by means of the orthopedic septo-columellar suture is absolutely essential and must be resorted to in every case This suture, however, applied in the conventional manner will fail to hold the tip in the elevated position unless it is supplemented by other means In a previous article,[1] I advised invagination to insure the elevated position of the tip, and the lip-freeing technique[2] (cutting the depressor septi nasi muscle fibers in the columella) to prevent the lip muscles from pulling the tip down With these additional methods of treatment, the tendency of the tip to return to its former low position is minimized and often eliminated

An attempt should be made to lower the cartilaginous dorsum of the septum to the level of the nasal tip, as was done in Type I, but this is not always possible There is a limitation to which we can lower the anterior surface of the septum It should never be lowered less than 30 degrees in the nasofacial angle, otherwise the nose would be too small, the profile too low, and the tip too snubbed For esthetic reasons, therefore, the tip must be raised above the level of the cartilaginous dorsum of the septum in every case of Type II and the orthopedic septo-columellar suture is the only means of doing so with a reasonable chance of success

CONCLUSION

When the orthopedic septo-columellar suture is contemplated in rhinoplasty, the first point to determine is the amount of projection of the nasal tip Nasal tips can be profitably divided into two types Type I with adequate projection, and Type II with inadequate projection

The orthopedic septo-columellar suture is never indicated in any case of Type I nasal tip and will not be necessary, providing the cartilaginous dorsum of the septum is lowered adequately

Overcorrection of the tip on the septum by means of the

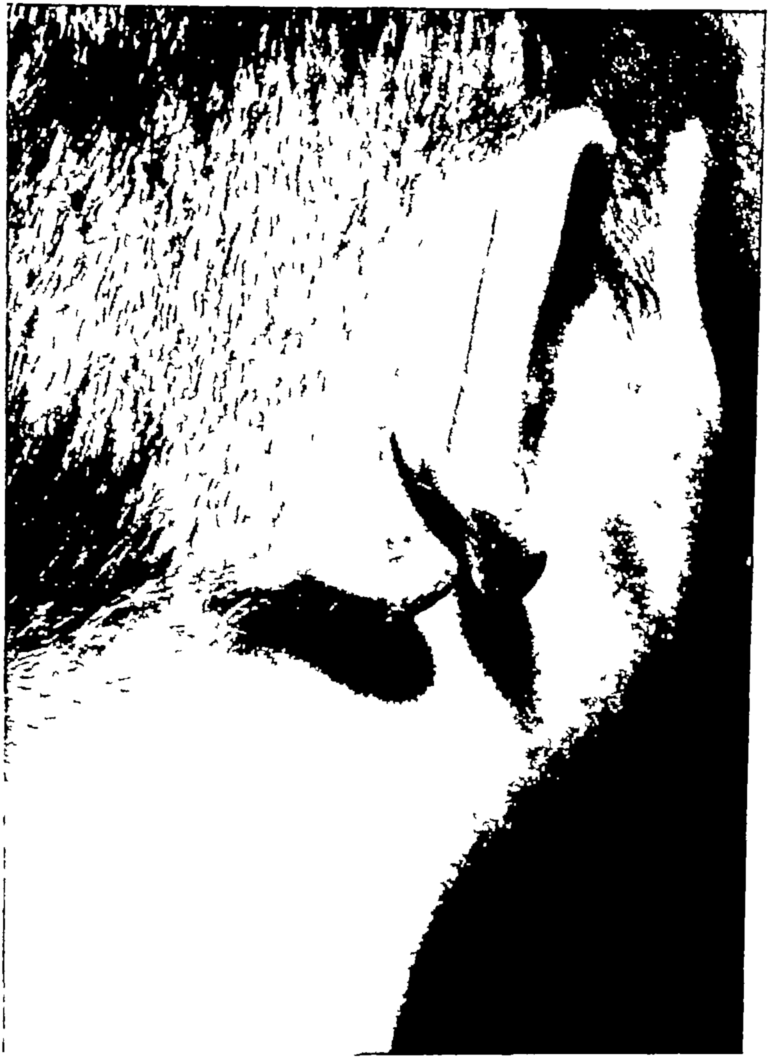

Fig 1 Photograph showing the tumor overlying the right mastoid process of a 13-year-old boy

three flecks of yellow white material up to 0 1 cm in diameter The remainder of the physical examination was not remarkable The ears nose and throat were essentially normal no change was noted in the faucial tonsils The examination of the heart lungs abdomen genitalia and extremities was as usual

Laboratory Studies Complete blood count and urinalysis were within normal limits The erythrocyte sedimentation rate was not elevated

MUMMIFIED EPIDERMAL CYST, CALCIFIED EPITHELIOMA OF MALHERBE

Report of a Case

S D Greenberg, M D ,*
and
F E LeJeune, Jr , M D ,†
Iowa City, Iowa

The modern otolaryngologist is frequently confronted with tumors of the head and neck An accurate diagnosis is always stressed, for such is important for clinical treatment as well as academic interest The case herewith reported was recently seen in the Department of Otolaryngology and Maxillofacial Surgery, and in the Department of Dermatology at the State University Hospitals, Iowa City, Iowa The exact nature of this tumor was not appreciated until a frozen section was done at the time of surgical excision

CASE HISTORY

The patient a 13 year-old boy was admitted to the State University Hospitals April 1, 1957 The chief complaint of the patient was a slowly growing tumor beneath the skin overlying the posterior aspect of the right mastoid process The tumor was of two and one-half years duration There was no history of fever cellulitis suppuration, fluxuation, or breakdown of the tumor Two weeks before admission the growth was incised by the referring physician and yielded several drops of blood There was no regional lymphadenopathy The patient lived on a farm and drank unpasteurized milk

Physical Examination

The patient was a husky young white male who appeared to be at the stated age of 13 years He was neither acutely nor chronically ill Oral temperature was 99 2° F pulse was 88/min and BP was 110/70 mm Hg The tumor was firm and non tender and was overlying the right mastoid process (see Fig 1) It was conical and measured 3 5 cm at its rounded base and 2 0 cm in height, it was freely moveable within the sub cutaneous tissues The overlying skin was reddish brown and contained

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*Dr Greenberg is a Resident in the Department of Otolaryngology and Maxillo-facial Surgery University Hospitals Iowa City Iowa

†Dr LeJeune Jr recently completed Residency Training in the Department of Otolaryngology and Maxillofacial Surgery University Hospitals Iowa City Iowa He is now in the Army Air Force stationed at Kessler Field Miss

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representing a pseudo-capsule Adjacent adipose tissue was present The tumor was composed largely of masses of eosinophilic material which varied in size and shape Some showed ghosts of former cells whose appearance was that of having originally been stratified squamous epithelium These cells had no remaining nucleus or visible cytoplasm and only the cell walls were seen (see Fig 5) Other eosinophilic masses were amorphous showing no cellular structure Within and about these eosinophilic masses there were minute foci of amorphous deeply blue staining bits of calcium (see Fig 5)

The stroma varied in composition being loose in several areas but appearing compact in most areas It was composed of strands of collagen and fibrous connective tissue In some areas an occasional fibroblast was seen Scattered about the stroma there was keratin debris about which there were several large foreign body giant cells and foci of lymphocytes (see Fig 5)

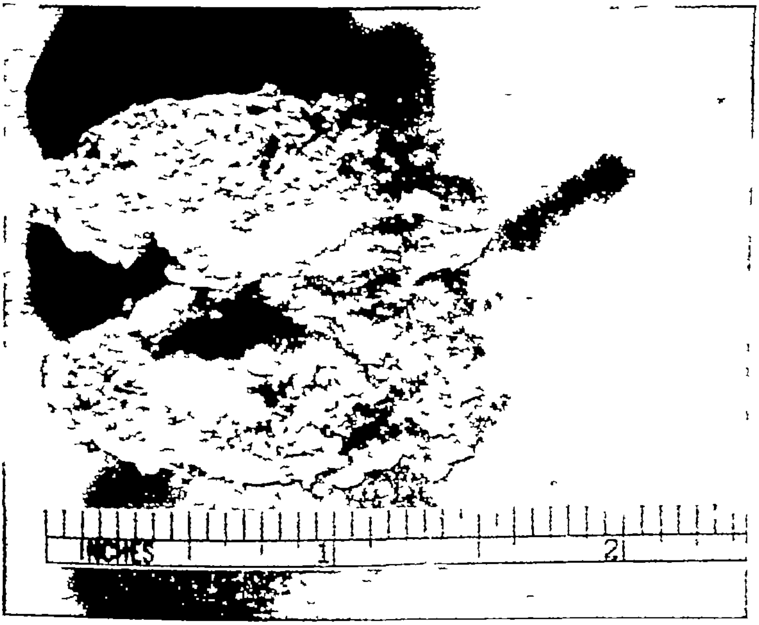

Fig 3 Photograph of the cut surface of the tumor

The most interesting feature was the large groups of actively proliferating epithelial cells which were intermingled within the areas of coagulative necrosis and amorphous keratin debris (see Fig 6) These cells were closely packed and had a large pale blue vesicular nucleus containing one to two nucleoli (see Fig 7) These cells resembled the basal cells of skin. The cytoplasm stained pale blue to light pink and the cell borders tended to be indistinct There were areas within these cell groups showing 4-5 mitoses per high power field (see Fig 7) Two fields showed transformation of these cell groups into degenerating

X rays of the paranasal sinuses showed minimal thickening of the mucosa of the right antrum An X ray of the tumor was interpreted as showing no calcification, chest X ray showed no change Serological test for syphilis was normal Intradermal tests for coccidiodomycosis, blastomycosis, and histoplasmosis were negative Intradermal second strength P P D test for tuberculosis was weakly positive

Hospital Course

The patient was seen in consultation by the Department of Dermatology whose impression was a low grade malignancy of connective tissue origin Excision was recommended The preoperative diagnoses included 1 Low grade malignancy of connective tissue origin, 2 chronic granuloma, and 3 possible xanthoma At the time of surgery the frozen section diagnosis was "Mummified Epidermal Cyst" The tumor was completely excised A primary closure was done, and post operative healing was uneventful

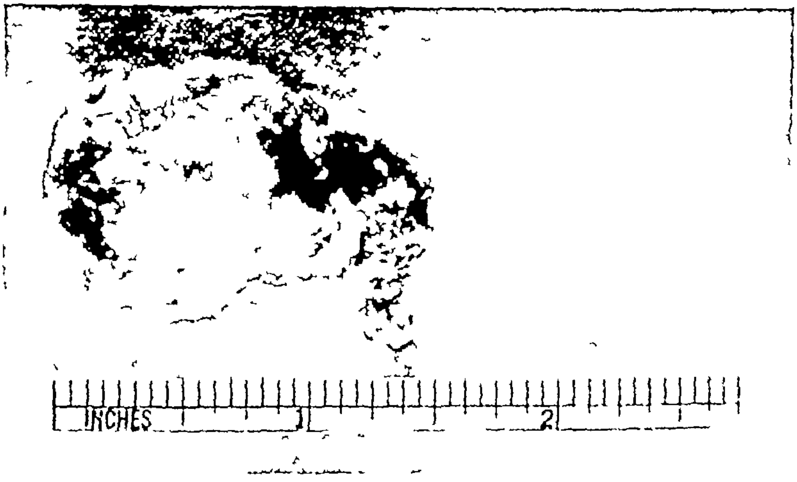

Fig 2 Photograph of the oblong irregularly lobulated tumor A portion of the closely adherent overlying skin is seen on the right

Gross Description The specimen consisted of an oblong irregularly lobulated firm grey brown tumor, measuring 1 0×2 5×2 0 cm (see Fig 2) An elliptical portion of overlying skin was closely adherent to the superior surface Attached fragments of adipose tissue were scattered about the surface On the cut surface (see Fig 3) the margins of the tumor were encapsulated by an intact covering of grey white tissue measuring 0 3 cm The central portion was composed of yellow grey compressed crumbly material which showed no particular pattern No odor was discernible

Microscopic Examination The tumor was within the subcutaneous tissues (see Fig 4) The stratified squamous epithelium of the overlying skin was well preserved and showed minimal acanthosis Within the compact dermis there was an increase in collagen and fibrous connective tissue and a sparse infiltration of lymphocytes

The tumor was bordered by a thin layer of compact connective tissue

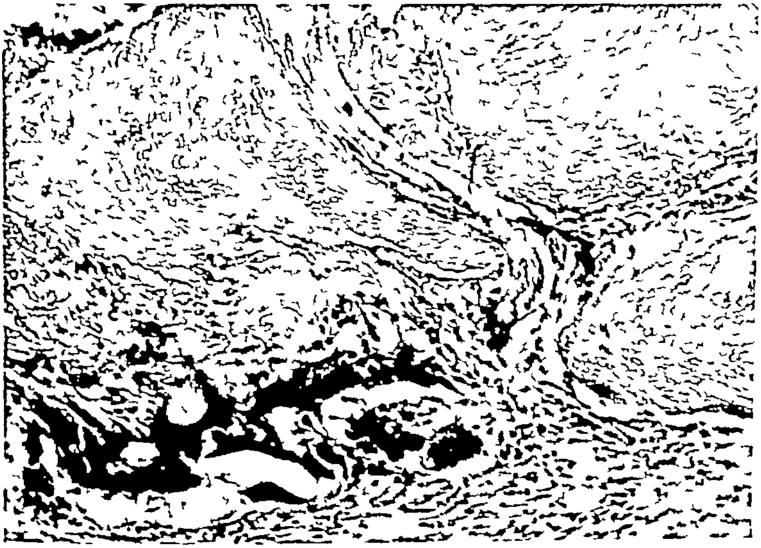

Fig 5 Photomicrograph showing three groups of ghost cells (degenerating stratified squamous epithelium) Within the stroma there are foreign body giant cells adjacent to keratin debris and flecks of calcium—300X.

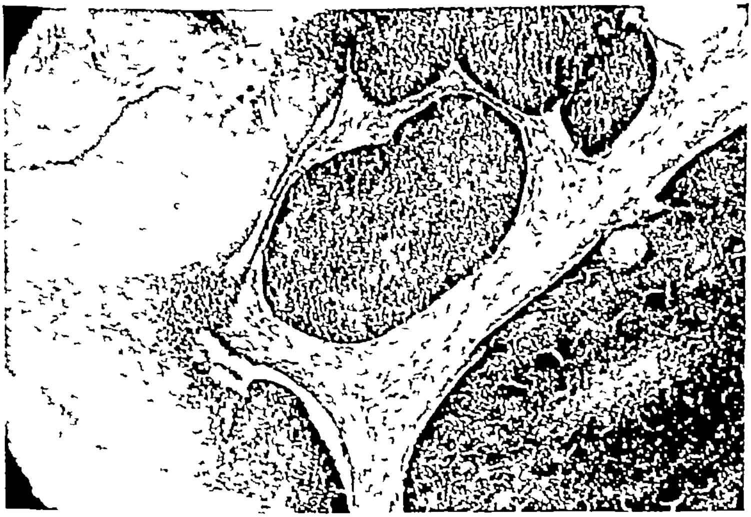

Fig 6 Photomicrograph showing groups of actively proliferating basal cell type epithelial cells The transformation of these basophilic cells into the shadow cells can be seen—100X.

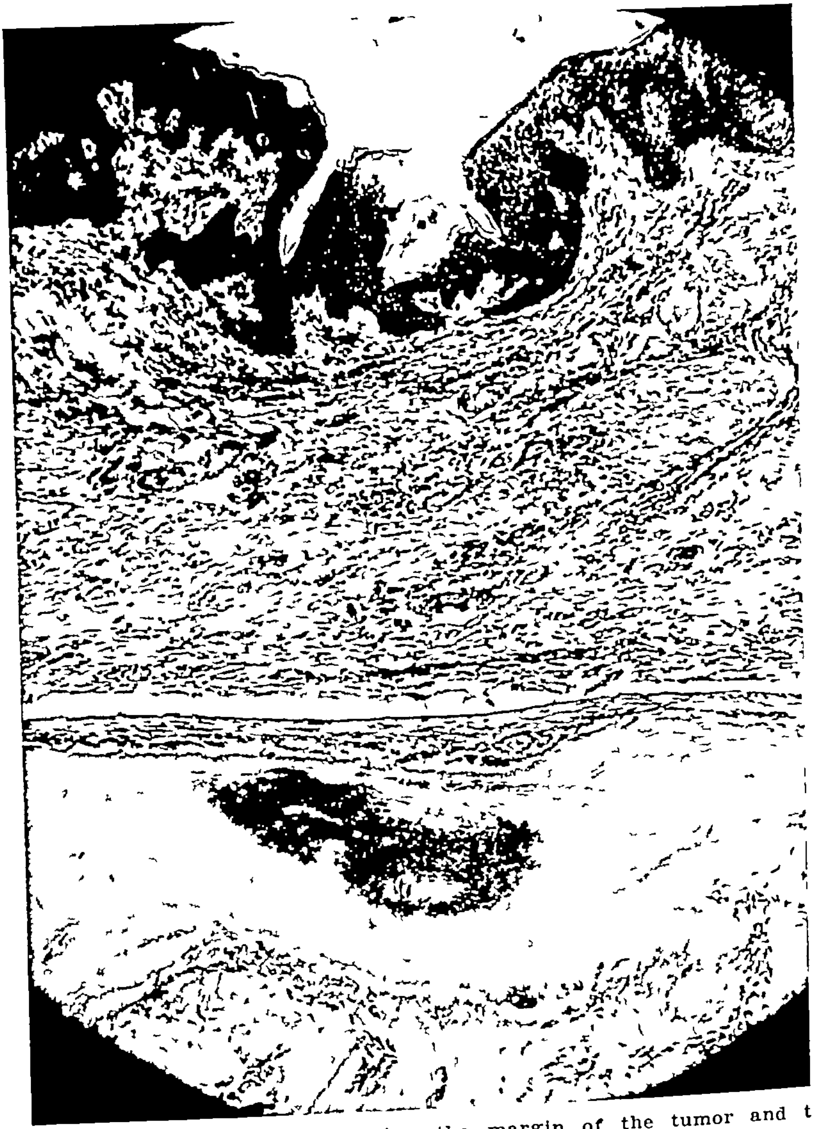

Fig 4 Photomicrograph showing the margin of the tumor and the overlying skin—75X.

stratified squamous epithelium In one focus there was dyskeratosis Two small keratin pearls were present within one basal cell group

DISCUSSION

This tumor was first described in 1880 by Malherbe (as cited by Lever[1]) It is unfortunate that Malherbe used the but it has recently been reported to be more common in childhood[4]

The growth may occur on the scalp, face, back, arm or thigh, but it is most common about the head and neck[5] The lesion is slow growing, and the majority have been present for an average of three years before being removed[6] The tumor is attached to the overlying skin, but it is freely moveable within the underlying tissues Rarely, there may be ulceration of the overlying skin[7] The tumor is non-tender and usually asymptomatic. It is rubbery to firm, to palpation Recommended treatment is surgical excision The most common preoperative diagnosis is a sebaceous cyst[4]

Grossly, the tumor usually measures between 1 0 to 4 0 cm in greatest dimension, although some have been reported up to 7 cm[3] The surface is grey-white, smooth to finely lobulated, and has particles of adipose tissue adherent to its thin capsule of fibrous connective tissue At times, the capsule is not complete The firm tumor often cuts with some difficulty because of the bits of calcium which are almost always present within its stroma[2] The cut surface is light tan to yellow brown, and varies from smooth to granular to crumbly[3] Microscopically, there are two basic cell types the "basophilic cells" or basal cell type, and the "shadow cells" (mummified epithelial cells) or squamous cell type[1 3]

The varying sized irregularly shaped groups of mummified or shadow cells are examples of coagulative necrosis, for although the cell borders are distinct, the nuclei and cytoplasm have undergone necrosis and do not stain In occasional foci the squamous type epithelial cells may show cornification, while in other areas this epithelial component may show dyskeratosis In other portions the necrosis may have progressed so that only amorphous hyalin debris remains

The basophilic cells, or basal-cell-like epithelial component are also found in varying sized groups There is no pallisading about the periphery of these groups, thereby differentiating them from basal cell tumors These cells have rounded to oblong prominent deep blue vesicular nuclei with one to two nucleoli The cytoplasm is scant and light blue with ill-term "calcifying epithelioma" in describing the lesion, for it neither metastasizes nor locally invades In 1933, Chin Kuang-Yu[2] reviewed the world medical literature on the subject, he postulated that perhaps these tumors arose from embryonic rest cells King,[3] in 1947, introduced the name of "Mummified Epidermal Cyst," for he believed, as do the authors, that the tumor is related to epidermal cysts of the skin In cases where there is a history of previous trauma to the skin overlying the tumor, there is little doubt as to the relationship of the tumor to an epithelial cyst or epithelial implant[3]

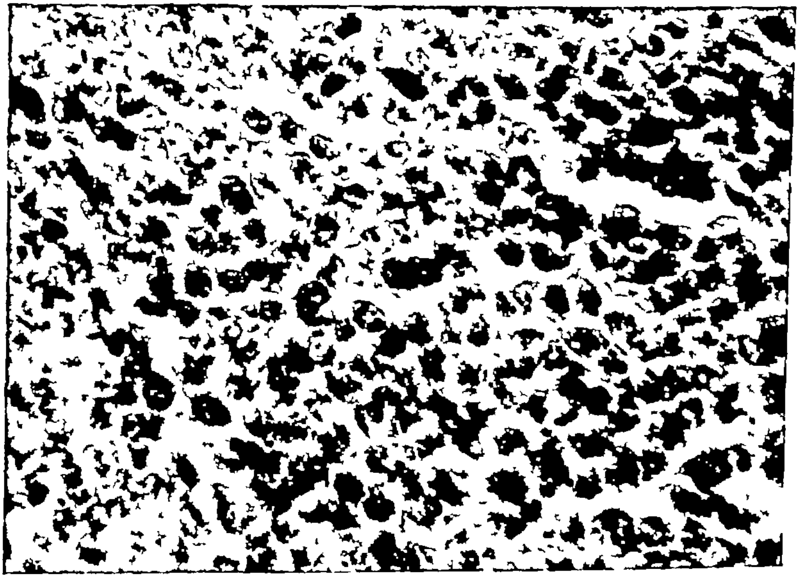

Fig 7 Photomicrograph showing the basal cell like epithelial component of the tumor Seven mitoses are seen in this field—600×

Various reports list different incidences for this tumor In the earlier report the incidence was sometimes one in ten thousand surgical specimens,[2] and in the later reports the incidence has been sometimes one in two thousand surgical specimens[3] There is apparently no difference in the incidence of the tumor according to sexes The tumor may appear any time between the ages of two years to 80 years,

4 CAWLEY, E P and WHEELER C E Calcifying Epithelioma with Emphasis on Its Occurrence in Children *South Med Jour*, 48 898 901 Sept., 1955

5 CASTIGLIANO S G and ROMINGER, C J Benign Calcifying Epithelioma of Skin *Arch Derm and Syph*, 70 590-600, Nov 1954

6 HIGHMAN B and OGDEN G E Calcified Epithelioma *Arch Path* 37 38 169 174, March 1944

defined cell borders Mitoses are not unusual In areas, one may see the transformation of the basophilic cells into the shadow cells [1]

Within the stroma there are varying scattered flecks of calcium, which stain blue-black with hemotoxylin and eosin There are also foci of foreign body giant cells about the keratinous debri The bulk of the stroma is composed of collagen and fibrous connective tissue

Although the microscopic picture of this tumor is easily recognized, a calcified epidermal cyst should be considered in the differential diagnosis Lever [1] states that a calcifying epithelioma of Malherbe differs from a calcified epidermal cyst, in that the latter does not contain the basophilic cells *or basal cell type This distinction, however,* is not universally recognized [3]

SUMMARY

1 Mummified epithelial cysts (calcified epitheliomas *of Malherbe) are relatively common tumors* of the head and neck

2 This tumor may occur in *any age* group, but it is most common in children

3 The lesion is slow growing, firm, sub-cutaneous, and freely moveable

4 The lesion has two basic cells types, the basophilic or basal cell type, and the shadow or mummified squamous cell type

5 The tumor does not *metastasize and does not* locally invade

6 The treatment *of choice is surgical* excision

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NEW CONCEPTS IN CORRELATION OF SURGICAL ANATOMY AND EMBRYOLOGY IN LATERAL CERVICAL VESTIGEAL STRUCTURES *†

M R HIMALSTEIN, M D ,

Bay Pines, Fla

The embryology of the cervical region is fascinating and complicated We may recall from our student embryology the phrase, ontogeny recapitulates phylogeny, or the embryological history of the individual organism recapitulates the history of the race The branchial arch structures represent that phase in the evolution of man wherein his forbears existed in an aquatic environment The word branchial is defined as pertaining to or resembling the gills of a fish Frazer[1] has several objections to the term branchial in describing this phase of development in man, especially since at no time are definitive branchial or gill structures formed in the recapitulation process The entire arch phase exists as a visible external structure for only three weeks Congdon[2] stated that the arches do not in any complete sense recapitulate their phylogenetic history, and that the process is much foreshortened and distorted

Most authors presenting a case of lateral cervical fistula stress the importance of embryology in understanding its surgical anatomy In attempting a correlation there are several points which tend to confuse The author was con-

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*Submitted as Candidate s Thesis to American Laryngological Rhinological and Otological Society Inc 1958

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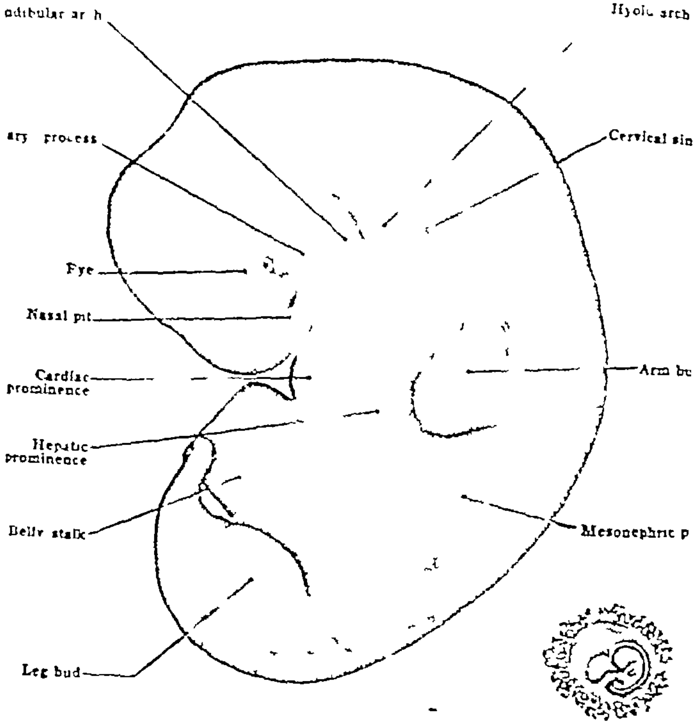

Fig 1 (Taken from Patten[9] by courtesy of the Carnegie Institution of Washington) A Human embryo late in the fifth week Length 6 5 mm retouched photo (×15) of embryo 6502 in the Carnegie Collection Small sketch lower right shows actual size of embryo

the post-branchial phase, the head is curled directly over the pericardium Frazer[4] ascribes this to the fact that the dorsal structures of the head at first grow more rapidly than the ventral structures As the neck develops, the ventral area grows more rapidly, and the head is lifted from the pericardium The arch field lies initially from before backwards with each arch disposed in a superior-inferior direction As the neck develops a ventral arc is described due to the rapid ventral expansion, and the structures derived from the arches as the mandible and subjacent transverse flexure line of the neck are disposed in an anterior-posterior direction For this reason the terms dorsal and ventral as opposed to superior fronted with a case of complete lateral cervical fistula which opened internally into the tonsil fossa, then passed beneath the posterior belly of the digastric muscle, coursed anterior to the region of the carotids, and opened externally near the sternocleidomastoid attachment to the clavicle According to older writings this would appear to be a fistula of the second pharyngeal pouch breaking through the closing membrane into the second branchial groove and emerging externally through the duct of the precervical sinus Wenglowski,[1] however, maintained that the hyoid bone marked the inferior level of the branchial arch region on the postembryonic neck and, because complete fistulae often open much lower, he presented his thymic duct theory in 1913, and a wide measure of acceptance was recorded The thymic duct itself, however, is a third pharyngeal pouch derivative, and according to embryologists the internal opening should be in the pyriform fossa and it should not pass between the internal and external carotids as the majority of complete fistulae do To add to the confusion, second pouch fistulae should course between the internal and external carotids and not anterior to both, as in the author's and other reported cases

A historical summary by custom should be inserted here, but it will be entered later so that it may be better appreciated By organizing the literature, correlating the anomaly with this literature, and with some arm-chair hypothesizing a tenable concept can be evolved in explanation of the mechanism of development of lateral cervical vestigeal structures which does not violate accepted embryological concepts While this theory is not intended to represent the complete answer, it *is at least a reasonable correlation of surgical anatomy* and embryology, the pieces of the puzzle fit together to make a whole picture, but whether it is "the" whole picture remains to be seen

THE BRANCHIAL ARCHES

Before proceeding it would be well to orient ourselves topographically with regard to the arch area on the side of the head As can be seen in Fig 1, before the neck develops in

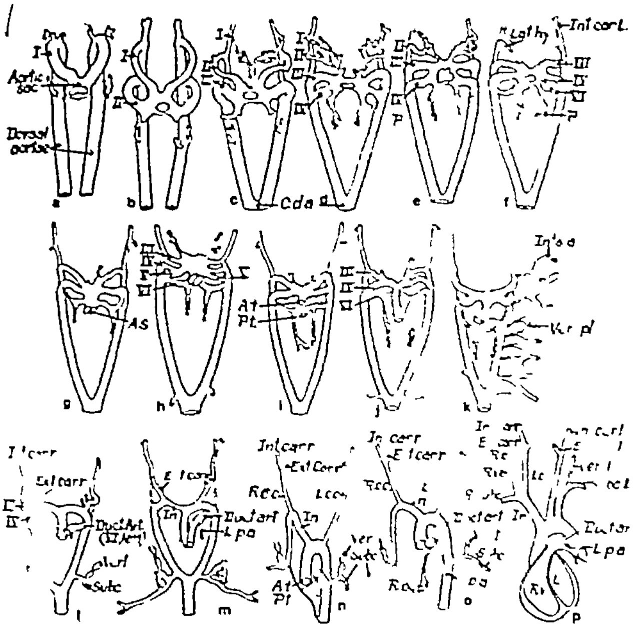

Fig 2 Ventral views of aortic arch system in a series of human embryos in the earliest stage only the first two arches are present The lengths of the respective embryos from which these diagrams were made are as follows a b 3 mm c d 4 mm e 5 mm f 6 mm g mm h 7 mm i 8 mm j k 11 mm l 13 mm m 14 mm n 16 mm o 18 mm p full term fetus

I to VI—aortic arches c d a common dorsal aorta int car r and l right and left internal carotid arteries ext car external carotid arteries In innominate artery vert vertebral artery subc subclavian artery A t aortic trunk

Note In g aortic arches I and II have completely disappeared In l external carotid artery appears from mid portion of aortic arch III In m the segment of dorsal aorta between aortic arches III and IV is disappearing to form the definitive common and internal carotid arteries—(From Congdon taken from Jordan and Kindred Textbook of Embryology 5th Ed D Appleton-Century Co 1948)

entodermal evagination corresponding to each ectodermal groove is termed a pharyngeal pouch These areas of contact or near contact are termed closing membranes and correspond to the gill membranes of aquatic animals

Some arch structures are evident before the arches are externally evident, e g Congdon reports the aorta of the first arch is present in a 1 3 mm , or 19-day-old embryo Similarly Frazer[4] reports that at the time the visible manifestation of

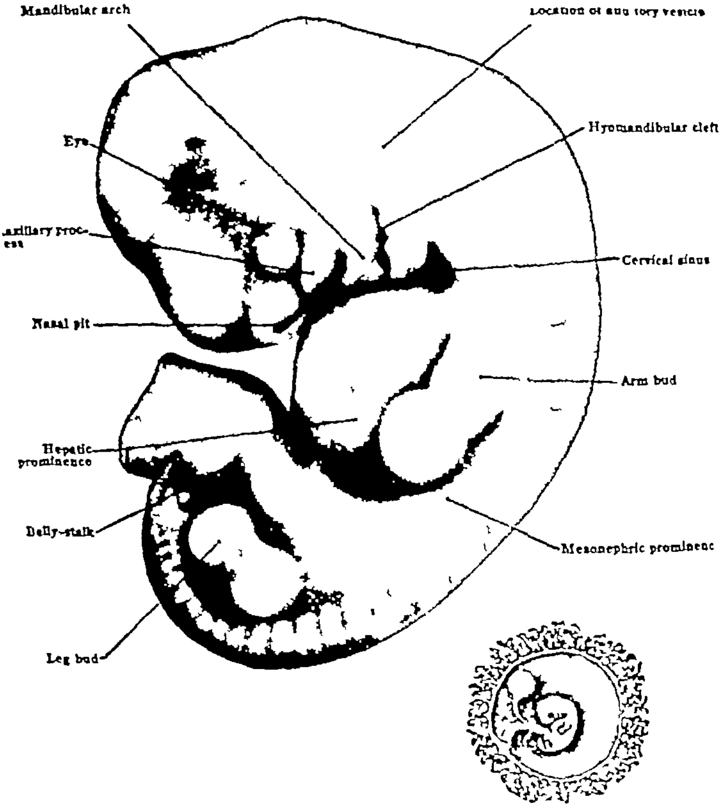

Fig 1 B About the middle of the sixth week Length 10 mm note cervical sinus further recessed and prominence of first and second arches with hyomandibular cleft or first groove

and inferior, and cephalad and caudal rather than anterior and posterior will be used

The arches appear externally from the fourth through the sixth weeks (embryo lengths 4 mm to 13 mm) Only four arches appear externally in man, the fifth and sixth arches not being represented on the surface The arches consist of mesodermal bars covered by ectoderm externally and entoderm internally Caudal to each bar, and numbered according to this bar, are the branchial grooves (clefts or furrows), here the ectoderm and entoderm approach each other, with the mesoderm in a relatively thin layer between them The

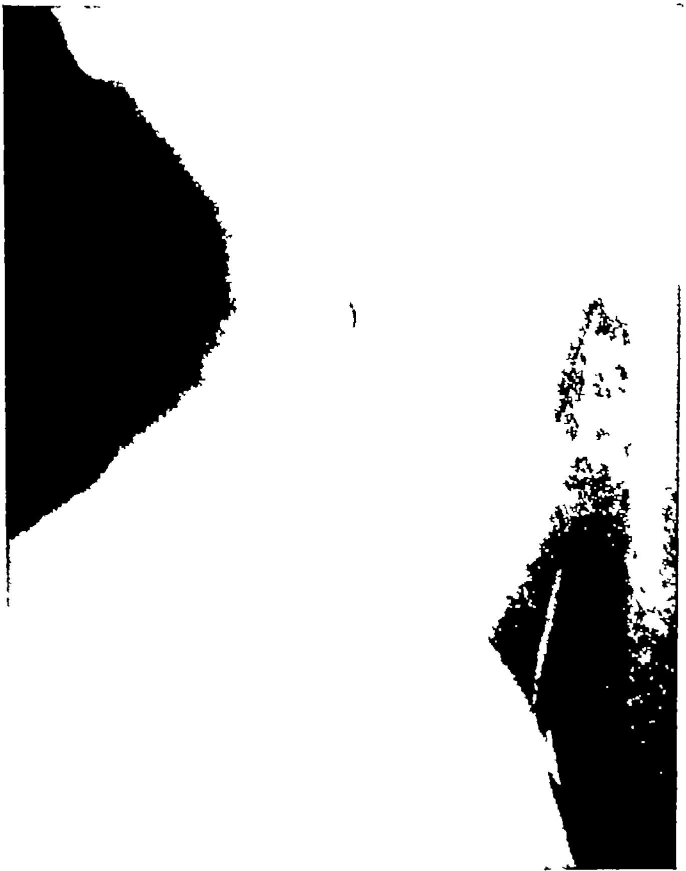

Fig 4 Lateral X-ray author's case with lipiodal filled tract Note its course anterior to the carotid sheath and just dorsal to the lesser cornu of the hyoid

For roentgenograms of complete fistulae surgically proven to have passed between the internal and external carotids and for a roentgenogram of a third pouch origin incomplete internal fistula suggesting a course dorsal to the carotid axis (not surgically confirmed) see Parsons Philip B Lateral Cervical Sinus Report of Three Cases with Brief Review of the Literature Amer Jour Roentgenol 67 757-762 May 1952

arch structures including the stylopharyngeus, the fistula may, and has, passed beneath, over or even through the muscle Much heated debate has ensued, the basis of argument revolving around the concept that if the anomalous fistula passed caudal to the third arch structure, the stylopharyngeus, the fistula should be of third arch origin As

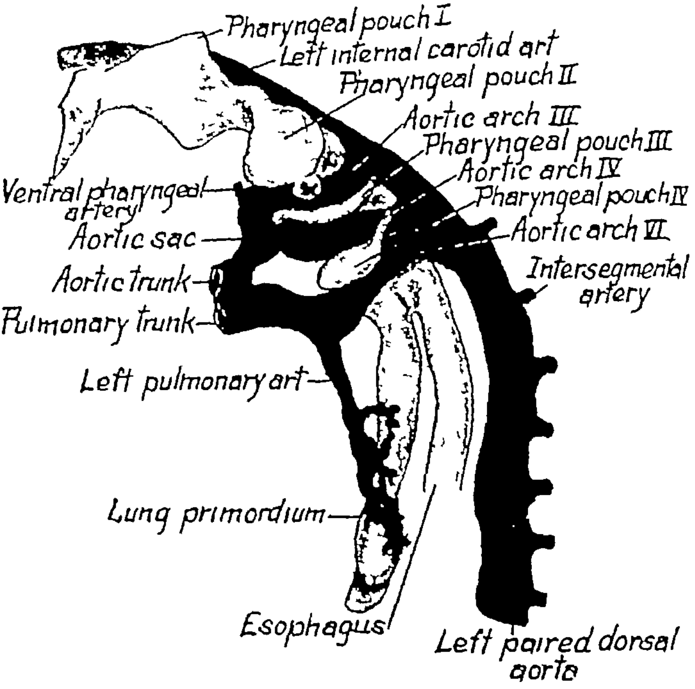

Fig 3 Laterial view of aortic arches of left side of an 11 mm human embryo The 'x was added by the author to mark the approximate site at which the external carotid artery will come off at the end of the arch phase (13 mm embryo)

Note Any third pouch derivative whether branchiogenic fistula or thymic duct vestige is related caudal to the common-internal carotid axis derived from aortic arch III (From Congdon taken from Jordan and Kindred Textbook of Embryology 5th Ed D Appeton-Century Co 1948)

the third arch externally is fading, the deeper structures associated with the arch have either disappeared or migrated

This process of appearance and disappearance, migration or non-migration, results in many controversies in regard to anomalies and their variation from case to case Several instances of this, in which earlier formed structures migrate or disappear before certain later structures appear, will be touched on in this paper For example, the stylopharyngeus muscle, a third arch derivative, migrates cephalad into the domain of the second pouch, and if an anomalous fistula develops from the second pouch, depending on the exact time of its development in relation to the migration of the third

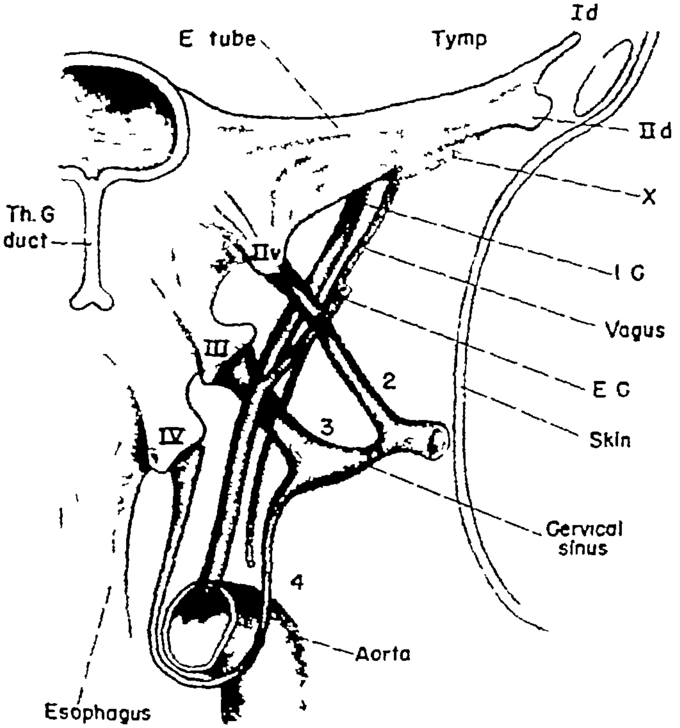

Fig 6 Schematic figure to show the vestigeal structures in the neck with their relations to main arteries and nerves I-d II-d dorsal angles of first and second lateral pouches II-v III IV internal pharyngeal ducts derived from ventral angles of second third and fourth lateral pouches 2 3 4 external pharyngeal ducts derived from second third and fourth external grooves X, layer of entodermal cells cut off from lower part of Eustachian tube E Eustachian tube E C external carotid I C internal carotid Th G Duct, thyroglossal duct Note Junction points of II-v III and IV with 2 3 and 4 respectively are the closing membranes —(As redrawn by Proctor[21] from Frazer[1])

coupled with the appearance and disappearance of major vascular structures in the branchial arch area

Each arch develops an aorta, a cartilage and muscle tissue and associated with each, but not developed initially within it, is a cranial nerve The Vth, VIIth, IXth and Xth nerves are associated respectively with the first, second, third, and fourth and fifth arches, the superior laryngeal division of the Xth nerve, with the fourth arch, and the inferior laryn-

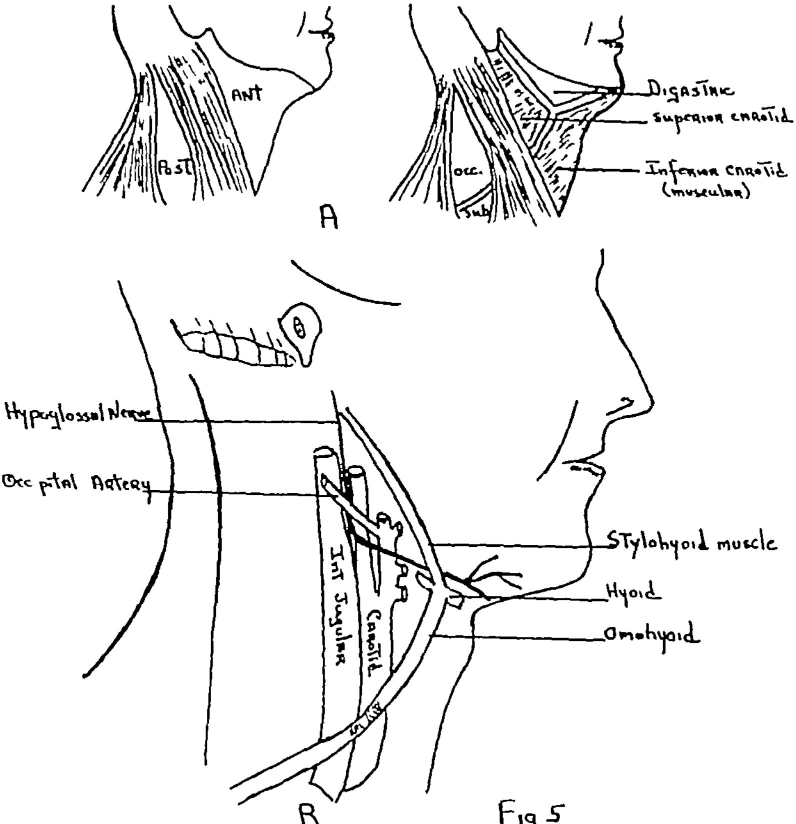

Fig 5

A Neck Triangles
Approximate area of superior and inferior carotid Triangles combined in Frazers Third arch area

B Carotid Axis-Hyoid Relations
Hypoglossal Nerve-Sternomastoid Artery Relations
The nerve may hook behind either the occipital artery or its sternomastoid branch In any event the peripheral passway sternomastoid branch always lies ventral to the nerve

will be brought out in this paper, the more pertinent criteria are the relation to vessels and nerves, and the site of internal opening for a fistula, relations to muscles, as with the stylo-pharyngeus, is not as decisive In the same manner it will be explained in more detail that whether a second pouch fistula passes between the carotid arteries or anterior or ventral to both, is a result of the developmental time lag, will of necessity pass caudal, or beneath the body of the hyoid, or through the thyro-hyoid membrane (see Fig 9) The muscles developed in the arches in some instances migrate a considerable distance, and their origin is identified by their innervation, *e g* , the occipito-frontalis is considered a second arch derivative, as it is innervated by the nerve associated with the second or hyoid arch, the facial or VIIth nerve The sternocleido-mastoid, tongue and infrahyoid muscles are thought to migrate from the occipital and upper cervical myotomes, as nerves from these regions innervate them The tonsil fossa is bounded by the palatoglossus and palatopharyngeus muscles, which are variously identified with the Xth and XIth nerves (via the pharyngeal plexus) and so cannot be definitely categorized as to arch of origin, if of arch origin In general, it can be stated that muscles are not always completely reliable guides in the study of branchial anomalies As Frazer points out, the most reliable relationship is to vessels and nerves, providing the vessels themselves are developed normally Wenglowski,[illegible] in his attempt to prove complete lateral fistulae were of thymic duct origin, claimed that fistulae opening in the region of the tonsil fossa, did not open into the fossa proper but were in relation to the palatoglossus, which he stated was innervated by the IXth nerve and so claimed this relationship indicated third pouch origin,

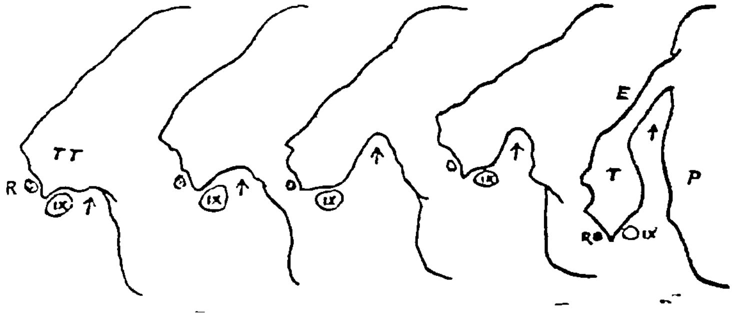

Fig 8 Outlines of left half of pharynx and tubo-tympanic recess (T T) in embryos of 16 18 22 26 and 35 mm seen from above to show the forward growth of the third arch (arrow) passing between the tympanum (T) and the pharynx (P) R Reichert s bar IX glossopharyngeal nerve E Eustachian tube —(From Frazer)

geal with the fifth arch The primitive arch aortae will be discussed in a separate section The cartilages develop into adult bony and ligamentous structures including the mandible, ossicles of the middle ear, the stylohyoid ligament, the hyoid bone and the laryngeal and thyroid cartilages The lesser cornu of the hyoid is derived from the second branchial arch,

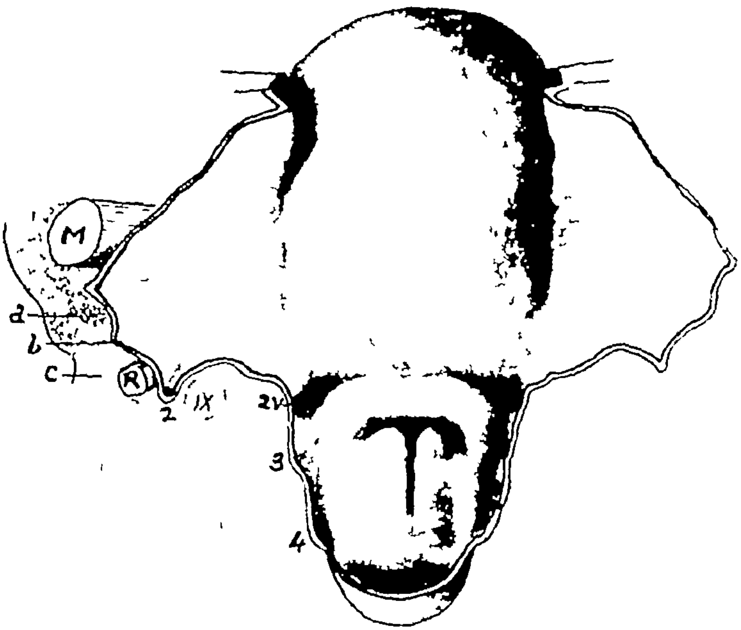

Fig 7 Pharyngeal floor in 16 mm embryo Tubo-tympanic recess marked off by a groove from the general pharyngeal cavity M R Meckel s and Reichert s bars IX glossopharyngeal nerve a condensation of handle of malleus b groove produced by this c mesoderm of second arch 2 dorsal and lateral part of second lateral pouch 2-V 3 and 4 levels of ventral ends of the corresponding lateral pouches Note the second pouch extends from the lateral extremity of the tubo-tympanic recess to the base of the tongue from 2 to 2-V (cf 2-V to 2 with II-v to II-d Fig 6) —(From Frazer[7])

as are the stapes, styloid process and stylohyoid ligament An elongated styloid process may actually join with the lesser cornu of the hyoid The body of the hyoid is derived from the third arch, therefore, congenital fistulae or other anomalous branchial vestiges of second pouch and groove derivation will of necessity course above the body of the hyoid and dorsal to the lesser cornu (see Fig 4), while third pouch derivatives in fact, as will be discussed more fully later, fistulae do open into the tonsil fossa proper, and also in relationship to the posterior pillar, and even to Rosenmuller's fossa

THE BRANCHIAL OR CLOSING MEMBRANES

In aquatic vertebrates the ectodermal and entodermal tissues of the grooves and pouches make direct contact to form the branchial or closing membranes, which break through normally to form the gill slits and subserve thus a respiratory function Only in the first groove and pouch in man is direct and measurable contact made which persists post-embryonally as the tympanic membrane Even here, in line with the distorted recapitulation mentioned in the introduction, Hammar (1902) and Wenglowski[5] report that in human embryos the first pouch and cleft cross each other in "X"-fashion so that while contact is constant it is limited in area to this point of crossing According to Wenglowski, even the mesodermal bar of the first arch is twisted so that the pharyngeal aspect of the arch lies crosswise to the outer aspect In the pouch and cleft relationships caudal to the first there is similar distortion the only consistency being that there is some area of contact between the second pouch and cleft to allow for closing membrane formation, though not always at the same level Hammar, quoted by Wenglowski, found in a 5 mm human embryo that the area of contact was with the ventral horn or extension of the second pouch, while Wenglowski, in a 6 5 mm embryo, found the area of contact with the dorsal extension For the third and fourth pouches and clefts the relations are more inconstant, with closing membrane formation sometimes occurring for the third, and even less likely for the fourth In Hammar's embryo the third and fourth pouches extended into the mesoderm unrelated to the grooves In a 6 5 mm embryo, Wenglowski found the greater part of a short third pouch taken up in forming a closing membrane In an 8 mm embryo, there was variation between the two sides on one side there was a small closing membrane, while on the other side there was a thick layer of mesoderm separating the pouch and cleft Piersol (1888) quoted by Hyndman and Light,[2] and Wenglowski concluded from a study of rabbit

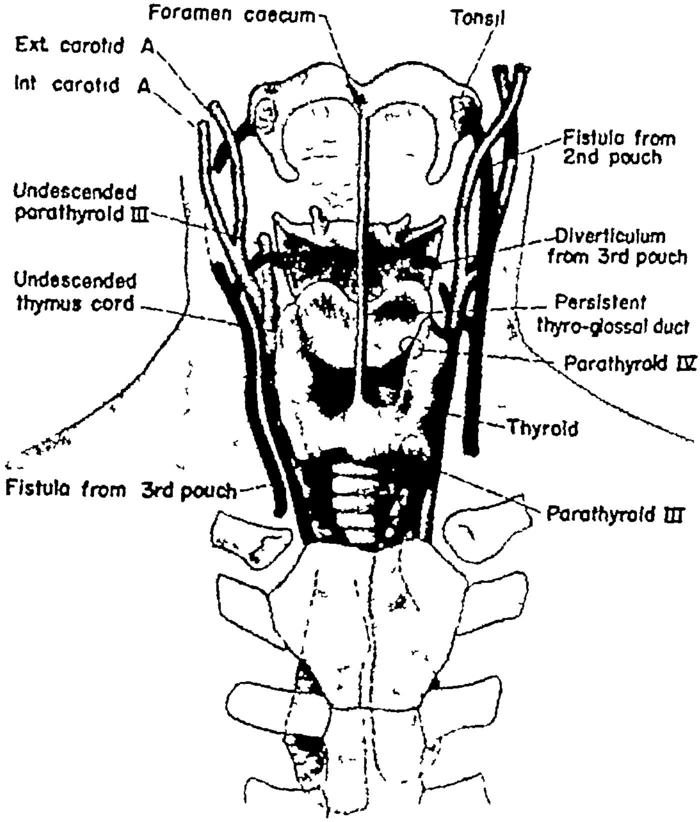

Fig 9 Schematic diagram from Braus Anatomie des Menschen Bd 2 as redrawn by Proctor[21] in which is collected a number of anomalous conditions On the subject s right note undescended parathyroid III residual thymus cord and a branchial fistula from pharyngeal pouch III A previous connection of the fistula with a diverticulum of the supratonsillar fossa is broken Center persistent thyroglossal duct. On the subject s left note a diverticulum of pouch III an incompletely descended thymus still attached to parathyroid III and a fistula of second pouch origin

Note The presentation on both sides of third pouch fistulae emanating from the thyro-hyoid membrane passing dorsal to the common carotid and then lateral to the great vessels however the presentation of the thymus cord passing medial and ventral to the carotid is not embryologically sound See Fig 3 and Frazer s Manual of Embryology[7] finitive form at the end of the arch phase from the mid-arch portion of the third arch aortae The dorsal aortae cephalad to the third arch continue as the internal carotids, and give rise to the ophthalmic and middle cerebral arteries Eventually the segments of dorsal aortae between the third and fourth arches disappear, to form the definitive internal carotids (see Fig 2, m) It must be assumed that a breakthrough from the second pouch to the second cleft, to form a congenital fistula, occurs in the arch phase, before the definitive external carotids are even formed In Fig 3 is Congdon's drawing of the lateral view of the aortic arches of the left side of an 11 mm human embryo, in the latter phase of the arch system, but before the definitive external carotids are formed I have taken the liberty of marking the approximate point of origin of the external carotid with "x" It is quite apparent that whether a fistula passes between the external and internal carotids, or ventral to both vessels, depends upon whether the external carotid links up with its cephalad course dorsal or ventral to the second pouch In several clinical descriptions the fistula courses between the carotids, and in the cases of Dowd,[15] Kleinert[16] and the author, the course is ventral to both The surgical significance lies in the fact that where the course is anterior or ventral to the carotids the surgery is rendered simple This relationship can be determined preoperatively by an X-ray study with the fistulous tract filled with a radio-opaque material It will be seen from the lateral X-ray (see Fig 4) that the tract crosses the hyoid almost at the lesser cornu, and lies far anterior to the usual course of the carotid sheath Where the tract crosses the hyoid more posteriorly, and is in topographical relation to the carotid sheath, it can be expected that the course will lie between the external and internal carotids, and the surgery rendered more difficult It also follows from Figs 3 and 6, that a third pouch derivative would have to course dorsal to the third arch vessels, the common, and, or internal carotids

Wenglowski admittedly could not follow the complex development of the arch vessels, and ignored these vessels in relation to the development of fistulae, he felt that muscle relations were more significant embryos that a breakthrough could occur only via the second closing membrane Carp and Stout[6] refer to Rabl's findings, that the second groove is deeper and persists longer, and so is the logical point at which a fistula could enter the pharynx They refer also to the progressively thicker layer of mesoderm between the grooves and pouches in the more caudal structures The third and fourth pouches are primarily concerned with the development of *the thyroid, parathyroid and thymus*

THE AORTIC ARCHES—ORIGIN OF THE EXTERNAL CAROTID ARTERY

The most recent and comprehensive study of the development and modification of the aortic arches of the human embryo is that of Congdon[2] (1922) The aortic sac or bulbus arteriosus, the heart primordium, communicates via the vessels of the branchial arches, termed the arch aortae, with the paired dorsal aortae (see Fig 2) Development of the arch vessels is accomplished by the fusion of dorsally growing sprouts from the aortic sac, with those growing ventrically from the dorsal aortae The first and second aortic arches disappear during the time the third pair of arches is forming (see Fig 2, a-f) A mandibular artery grows into the region *formerly occupied by the first aortic arch*, and a stapedial artery replaces the second aortic arch in the second or hyoid branchial arch These secondarily formed arteries are branches of the dorsal aorta, and have no continuity with the aortic sac It has apparently been assumed that the arch aortae of the second arch develop into the external carotids Obviously this is not so The arch aorta of the third arch is the most cephalad one, which persists as the primordium of an adult vessel The third aortic arches persist as the roots of the internal carotid arteries and from their anterior surfaces, just about the end of the branchial arch phase in point of time, there arise the external carotid arteries (see Fig 2, l) , hence, the base of each third arch between the external carotid and the aortic sac becomes the common carotid artery (see Fig 2, n)

To repeat for emphasis, the aortic arches of the second branchial arches disappear and take no part in the formation of the external carotid arteries which first appear in de-takes place, however, long after the arch phase has passed, that is, in the fourth month The crypts form in the lower portion of the angle The upper part hangs over this ingrowth as the supratonsillar fossa Lymphoid tissue infiltration takes place even later

In Wenglowski's time there was considerable controversy over the relation of fistulous openings to the stylopharyngeus muscle, which is innervated by the IXth nerve which courses just deep to it Being innervated by the IXth nerve, it is a third arch derivative As described above, however, the third arch mesoderm secondarily migrates into this area during the arch phase of development It would seem, therefore, that a fistula opening into the pharynx in this region emanates from second pouch area, and its relation to the stylopharyngeus muscle is accidental and of secondary importance in determining the origin of the fistula (see p 4 section on Arches) It would appear that a fistula opening anywhere from and including the tonsil fossa to the region of the Eustachian orifice is consistent with second pouch origin providing, of course, vascular and nerve relations are consistent with this Various sites of fistula opening mentioned in the literature are the supratonsillar fossa, Rosenmuller's fossa, posterior pillar, tonsil fossa proper and even just below the tonsil fossa In the author's case, dye injected into the tract preoperatively appeared in a large upper pole crypt Taylor and Burwell (1954) reported several cysts as residuals of the second pouch, which extended from the tonsil fossa to the region of the Eustachian orifice In two of these cases the cysts were bilateral, minimizing any contention that these might be ordinary retention cysts

The third pouch, like the second, develops dorsal and ventral angles The internal opening of a vestige of the third pouch would have to be related to the pyriform fossa, according to embryologists Its relationship to the carotid axis should be caudal If there were a closing membrane breakthrough with a complete fistula, it should open externally similar to a second membrane fistula The only difference from a second pouch complete fistula then would be in the level of the internal opening and the carotid axis relationship There is no case on

FATE OF THE PHARYNGEAL POUCHES—THE THYMUS

The foregut is a prolongation of the primitive intestinal canal There is no coelomic channel on either side of the gut at this level, the entoderm being separated from the ectoderm by solid mesoderm, thus, with general growth of the region the primitive pharynx increases in breadth Condensations in the lateral mesoderm cause thickenings to form the arches The lateral portions of the widened pharynx expand in a dorso-ventral plane to form the lateral pharyngeal pouches between the indentations caused by the arches The lateral pouches develop dorsal and ventral portions or angles The ventral angle of the first pouch is obliterated The dorsal angle, in conjunction with the dorsal angle of the second pouch, forms the tubo-tympanic recess (see Figs 6, 7)

In the case of the second lateral pouch the distance between the angles increases rapidly The dorsal angle is incorporated into the tubo-tympanic recess from which are formed the Eustachian tube and middle ear space The ventral angle extends from the Eustachian orifice to and including the tonsil fossa region According to Frazer, the separation of the dorsal and ventral angles takes place in this manner as the *tubo-tympanic recess is formed, the second arch lies ventral to the recess, the first arch comes to form the sloping cephalad wall and the third arch the caudal wall* The second *arch growth is most effective externally*, and it is a prominent structure externally *with its groove forming the transverse flexure line of the post-embryonic neck* The third arch, on the other hand, has its most effective growth *internally* Its internal bulge first delineates the tubo-tympanic recess caudally By continued growth of the third arch it approaches the first arch cephalad, thus narrowing the tubo-tympanic recess medially to form the definitive Eustachian tube and separating the dorsal and ventral angles of the second lateral pouch (see Fig 8) The ventral angle of the second pouch can then be seen to occupy the area laterally from the Eustachian orifice to the base of the tongue External to this entodermal expansion of second pouch origin is the third arch mesoderm From this ventral angle, entodermal ingrowths into the mesoderm form the tonsil crypts This herents claiming for them entodermal origin[9] Muscle and glandular tissue are not a part of normal post-embryonic thymus tissue, though commonly found in lateral fistulae

The origin of Hassall's corpuscles, the distinctive constituent of thymic tissue, is most controversial Frazer points out that there develops in some lower mammals a "superficial thymus" in association with the ectoderm of the third cleft His, in 1881, thought the thymus developed from the floor of the cervical sinus in the region of the third cleft, but later changed his mind Wenglowski in 1913, in attempting to explain stratified squamous epithelium in complete lateral fistulae which he claimed were vestiges of the thymic duct, stated the thymic tract is in relation to the third cleft in the sinus and has been seen to join with this ectoderm, and mentions this ectoderm as a possible source of Hassall's corpuscles He stated, however, that this taking on of ectoderm from the cervical sinus occurs only in those cases of fistula in which ectodermal, as well as entodermal, epithelium lines the tract

Norris[10] in 1938 described what he terms the discovery of the origin of Hassall's corpuscles He states that the ventral horn, or angle of the third pouch, contacts the ectoderm of the third branchial cleft in the precervical sinus, and that a portion of this cleft buds and joins the thymic anlage as an onlay covering the entodermal thymus cord to form the cortex containing the Hassall's corpuscles Maximow and Bloom,[11] in their textbook of histology, state however, that Hassall's corpuscles are predominantly medullary Garrett[12] in 1948 was unable to corroborate Norris' claim of a contribution of sinus ectoderm to the thymus, in fact, Garrett found that the thymic anlage coursed near, but received no contribution from the placodal duct of the Xth nerve rather than the third cleft, and took exception to Norris' illustrations on this point It is evident that an ectodermal contribution to the thymus has not been unequivocally established

Aside from the rare possibility of a persistent thymic duct, it is not unusual for bits of thymic tissue to remain in the cervical region, posterior and lateral to the thyroid lobes, or associated with parathyroid III (Ungerson, 1906, Gerard, record having the relations outlined above for a complete third pouch fistula

From the dorsal angle of the third pouch develops that portion of the parathyroid gland not derived from the fourth pouch, or parathyroid III From the ventral portion develops the thymus in the fifth or sixth week There is little actual descent involved, as it lies almost at once in relation with the pericardium to the lateral side of the great vessels The distal end of the duct enlarges to form the definitive thymus, while as growth goes on the stalk, elongates and then loses its pharyngeal connection and its lumen is obliterated The duct, by necessity, if it is of third pouch origin, has to emerge caudal or dorsal to the common-internal carotid axis, the artery of the third arch (see Figs 3, 6) This is the same relationship which would have to occur for an anomalous branchiogenic structure as a fistula Frazer describes the course of the thymic duct as given above, emerging from the third pouch, coursing dorsal to the carotid axis and then extending lateral to these vessels to the pericardium In older diagrammatic representations (see Fig 9) a different course is shown for a third pouch branchiogenic fistula (which is shown taking the expected course) and the thymic duct The thymic duct is shown emerging from the thyrohyoid membrane, consistent with third pouch origin, but it then turns down medial to the carotid axis Wenglowski admittedly could not follow the complicated development of the carotid vessels and discounted them as guides as to origin of fistulae He described the thymic duct as coursing "contiguous" to the vascular sheath, but does not specify as to whether it is contiguous dorsally, medially, laterally or ventrally It seems logical and consistent, however, in the light of Congdon's (1922) description of the aortic arch system and Frazer's description of the course of the thymic duct, to hold to these criteria in interpreting the origin of fistulae

The thymus briefly consists of a cortex and medulla, not sharply differentiated, and contains lymphoid tissue, Hassall's corpuscles and a stroma The origin of these elements, entodermal or otherwise, is controversial Even the syncitial portion of the connective tissue and lymphoid cells have ad-fourth, until in this manner the second groove and the more caudal arches and grooves are covered in by the second arch Rabl, in 1886, claimed the third arch did not override the fourth Rabl, in 1907, described a fusion between the second arch and the thoracic wall precursor as the means by which the sinus is closed According to Frazer, Rabl worked with moles and not human embryos[4]

The following description of the closure of the precervical sinus, based on Rabl's work, has for a long time been accepted The sinus is at first widely open laterally As the second arch grows caudally the opening of the sinus is narrowed to a duct, the precervical duct After closure of the duct externally, a closed space is formed, enclosing the second, third and fourth grooves, and the third and fourth arches (see Figs 6, 10) If one of the closing membranes breaks through, a communication is established between the primitive pharynx and the sinus, and if the precervical duct remains patent, a complete fistula is established With further growth of the embryo, the grooves entering the sinus are elongated into ducts and the arrangement described is that of the third and fourth ducts joining to form the precervical duct with the second groove duct opening into the neck of this precervical duct (see Fig 6) Eventually the ducts and sinus are narrowed and obliterated The explanation of whether a complete fistula opens high or low in the neck, based on this concept, depends on the length of the precervical duct, however, Wenglowski, Frazer and Garrett maintain, as shown below, that the third arch is not obliterated in the precervical sinus, and so makes difficult an explanation of the external opening of lateral fistulae based on a breakthrough of the second closing membrane communicating externally via the duct of the precervical sinus Wenglowski and Frazer hold that while the second arch grows much larger than the third, the third is not telescoped by it, and it is the third arch which fuses with the thoracic wall Wenglowski's contribution was that he first noted that the third arch was not obliterated in the precervical sinus development He erred, however, in maintaining that the third arch could not be represented postembryonically below the level of the hyoid Actually, the hyoid

1928, Norris, 1937) Conversely, a case with parathyroid tissue within the thymus is on record (Churchill and Cope, 1934) *Failure of descent* or *a true cervical thymus*, on the other hand, is rare

In summary, what should distinguish a complete fistula of third pouch origin from a fistula of thymic duct origin? For both, they should open internally in the pyriform fossa, pierce the thyrohyoid membrane and course dorsal or caudal to the carotid axis Frazer traces the course of the thymic duct as lateral to the great vessels to the thorax, while Wenglowski traces the course as "contiguous" to the vascular sheath and then along the anterior border of the sternomastoid A third pouch fistula, or a second pouch fistula for that matter, has an external opening embryologically through the corresponding branchial groove A thymic duct normally has no external opening, and Wenglowski, as will be discussed under "The Refutation of the Thymic Duct Theory," explains this as due to secondary suppuration

The fourth pouch contributes parathyroid IV A vestige of fourth pouch origin, because of its relations to the aorta of the fourth branchial arch, would have to loop around the aorta on the left or the subclavian artery on the right, as these are fourth arch aortae derivatives (see Fig 6) No such relationship has ever been reported for a fistula, also, should such a fistula exist, it would course caudal to the superior laryngeal nerve, the nerve associated with the fourth arch

THE DISAPPEARANCE OF THE PRECERVICAL SINUS

Initially the four external arches are equally distinct on the ventral aspect of the head The first and second arches grow *more rapidly, and soon the precervical sinus* is a depression between the second arch cephalad and the caudal margin of the sinus field, the precursor of the posterior neck and chest wall (see Fig 1-A) In this depressed area are the third and fourth arches and the grooves of the second, third and fourth arches His, in 1881, described the formation of the precervical sinus as a telescoping process, cephalad to caudad, with the second arch *overriding* the third, and the third the

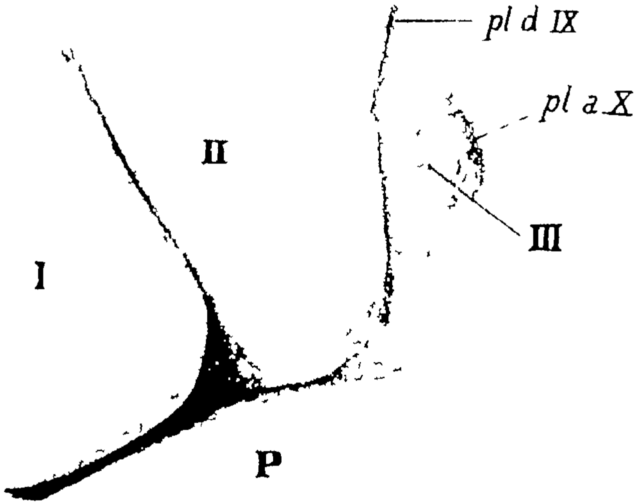

Fig 11 Region of the precervical sinus in a 10 mm embryo left side I II III branchial arches P pericardium pl d IX placodal duct of IXth nerve pl a. X, placodal area of the Xth nerve The widely open placodal recess of the vagus pl a X, is below and behind the narrow duct, pl d IX, leading to the glossopharyngeal ganglion The epipericardial ridge is very prominent below and behind the third arch The shaded area at the upper end of the first groove will develop into the pinna the second groove will become the transverse flexure line of the neck and the ectoderm over arch III will occupy the approximate region of the anterior triangle of the neck Visualize as the head lifts from the pericardium the region I II and III rotating clock-wise with the fulcrum at III (see Fig 16) —(From Frazer[4])

the hyoid, dorsal to the lesser cornu and beneath the posterior belly of the digastric, was ignored by Wenglowski in his claim that these were more properly of thymic duct (third pouch) origin

Frazer,[4] in 1926, working with human embryos, confirmed that the third arch is not obliterated in the precervical sinus, and in addition showed by logical inference that it is represented on the post-embryonal neck as the approximate region of the carotid triangles (see Fig 5) Dorsally the sinus area is bounded by the paraxial tissues delimiting the upper extremities of the third and fourth arches and their respective

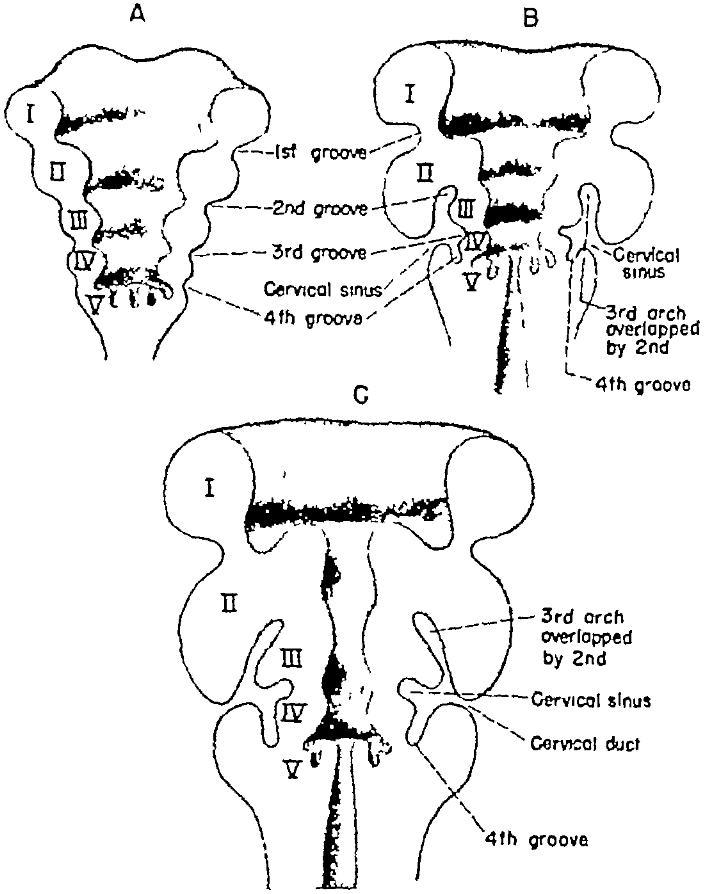

Fig 10 Showing early development of the pharyngeal wall A Showing proximity of ectodermal floor of branchial clefts to entodermal pharyngeal pouches B Rapid growth of the (hyoid) arch II overshadows postoral arches forming the cervical sinus C Occlusion of the cervical sinus

Note This is based on the old concept of Rabl Contrast with Figs 11 13 15 —(As redrawn by Proctor[21] from Ward and Hendricks[18])

is formed from both the second and third arch cartilages, with the second arch forming the lesser cornu and the third arch the greater cornu and body, thus a second pouch origin fistula passes above the hyoid but posterior to the lesser cornu The level of the second or hyoid arch is more accurately described as that of the posterior belly of the digastric and stylohyoid muscles, which are second arch derivatives, innervated by the VIIth nerve The course of lateral fistulae over veloped the clavicle, and ventrally its cell tracts contact the hyoid bone rudiment

Only the first or mandibular arches meet ventrally in the midline The ventral extremities of the more caudal arches are separated, with the gap progressively wider for the more caudal arches In apposition to this area of gapping is the pericardium (See Fig 12) The epipericardial ridge, as already described, turns medially beneath the ventral extremities of the third and second arches and then its cell tracts course between the pericardium ventrally and the pharynx dorsally to bury themselves in the mandibular arches In this interval between the arches ventrally are developed the tongue muscles and hyoid bone rudiment

At this early stage, Frazer calls attention to the presence of areas of thickened ectoderm, the placodal areas, in the paraxial boundary tissue dorsal and caudal to the sinus field This ectodermal thickening later becomes anatomically related to the nerve rudiments of the deeper lying ganglia of the IXth and Xth nerves Similar more cephalad thickenings are related to the Vth and VIIth nerve ganglia They appear to make no vital contributions to the nerves mentioned, and Frazer admits ignorance of their possible function Arey[15] states that epibranchial placodes originate at the dorsal ends of the branchial clefts, and in some lower vertebrates cellular proliferation from them clearly adds to the neighboring ganglia In higher animals and man, Arey states that the relations are less plain, and indications of contributions to the ganglia is in dispute Regardless, these ectodermal placodes overlay the upper part of the third arch and adjoining second cleft in relation to the deeper lying IXth nerve ganglion and encompasses also the greater part of the fourth arch and the caudal boundary of the field in relation to the Xth nerve ganglion By a process of thickening and infolding the placodes are first recessed and then form ducts leading to expanded vesicles in relation to the respective nerve ganglia Eventually the vesicles and ducts are obliterated In this process of thickening and infolding the structures of the cervical sinus are secondarily and passively affected The fourth arch is completely engulfed The duct of the IXth placode grooves, which make up the depressed area of the cervical sinus This paraxial tissue is continued caudally and ventrally The ventral continuation of this boundary tissue is known as the epipericardial ridge (see Fig 11) and is interposed between the ventral extremities of the second, third and fourth arches and the pericardium The ridge passes medially beneath the ventral extremity of the third arch, but the tract of cells forming the ridge continues forward to pass internally to the lower end of the second arch. The ridge thus connects the arches with the pericardium as far forward as the level of the second arch In the ridge are found structures vital to this discussion, namely the sternomastoid and infrahyoid muscles and the XIIth nerve Within its area is also de-

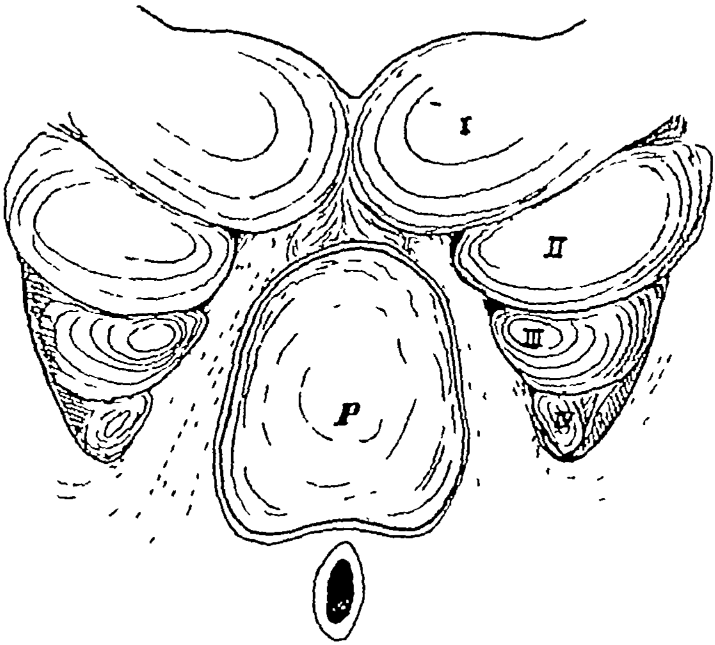

Fig 12 Semi schematic view of the lower aspect of the pharyngeal region the pericardium having been removed save for its roof I II III IV pharyngeal (branchial) arches P roof of pericardium The whole region is somewhat flattened out to show the relations Between the pericardium and ventral arch extremities is shown the extension of the epipericardial ridge (dotted lines) In this area will develop the tongue muscles and hyoid rudiment —(From Frazer[4])

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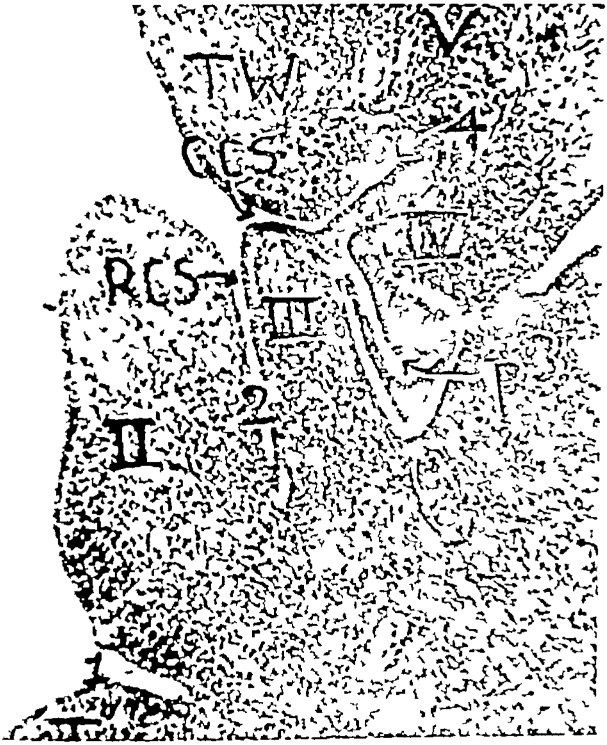

Fig 13 Human embryo 10 5 mm right side × 52 Third cleft obliterated I II III IV branchial arches 1 2 first and second branchial clefts 4 fourth branchial cleft engulfed by placodal duct of Xth nerve p-3 tip of third pharyngeal pouch RCS and CCS rostral and caudal parts of the cervical sinus TW thoracic body wall V vagus nerve In the preceding microphotograph in Garrett's paper that of an 8 mm embryo the placodal duct of the IXth nerve is shown as a dorso-caudal evagination from the second cleft into the tissue of the third arch to come into relation with the glossopharyngeal trunk The placodal vesicle of the Xth nerve reaches its greatest prominence later at about 12 mm when the last traces of its connection with the cervical sinus become obliterated —(From Garrett, F D Development of the Cervical Vesicles in Man[1] Fig 1 Plate I Anatomical Record 100 111)

and Xth nerves, or expressed simply, the cervical sinus obliterates by a fusion of its ectodermal lining from within toward the surface Second, he demonstrated that the third arch contributes to the formation of the ventral portion of the neck, namely, the area of the carotid triangles In effect, nevertheless, the third arch fuses with the precursor of the posterior neck and thoracic wall

At the time of the last flattening out of the third arch the can be seen (see Fig 11) to be located above the third arch in relation to the dorsal extent of the second groove According to Garrett, it forms an appendage to the second cleft Frazer states the thickening and infolding bulges above but does not cover or invade the third arch area Garrett,[12] in confirming and enlarging on Frazer's findings in 1948, states they have since been completely overlooked in the anatomical literature, and almost so in the clinical literature What older writers described as the precervical sinus disappearing through a fusion of the second arch with the thoracic wall, with the sinus reduced to an ectodermally lined cyst opening on the surface by a duct, has been disproven The precervical sinus itself is never closed off to form an ectodermal lined cyst, only the placodal ducts are involved One of Garrett's microphotographs in particular startlingly resembles the description of the precervical sinus duct arrangement of earlier writers, namely, that of the third and fourth clefts opening into the duct of the precervical sinus with the second cleft opening into this duct What appears to be the fourth cleft, however, is labeled the placodal duct of the Xth nerve with the third cleft obliterated, but with the third pouch appended to it but separated by a thin layer (see Fig 13)

The disappearance of the third arch as a projection on the surface is explained on the basis that the arch is concerned in the formation of many important structures in and about the pharynx, but not on the surface, and its appearance in the first place is only the result of its growth and condensation when the wall of the pharynx is relatively thin The second groove, on the other hand, outlines and maintains the prominence of the second arch because it becomes the transverse flexure line of the neck The second arch remains prominent posteriorly also, because from it and the adjoining first arch posteriorly are developed the pinna (see Fig 14)

To summarize Frazer's contributions here, he demonstrated, first that the cervical sinus was not obliterated by a fusion of the second arch with the thoracic wall precursor to enclose an ectodermal sac Rather, he showed that the branchial structures involved in the sinus are passively affected in the development and obliteration of the placodal ducts of the IXth

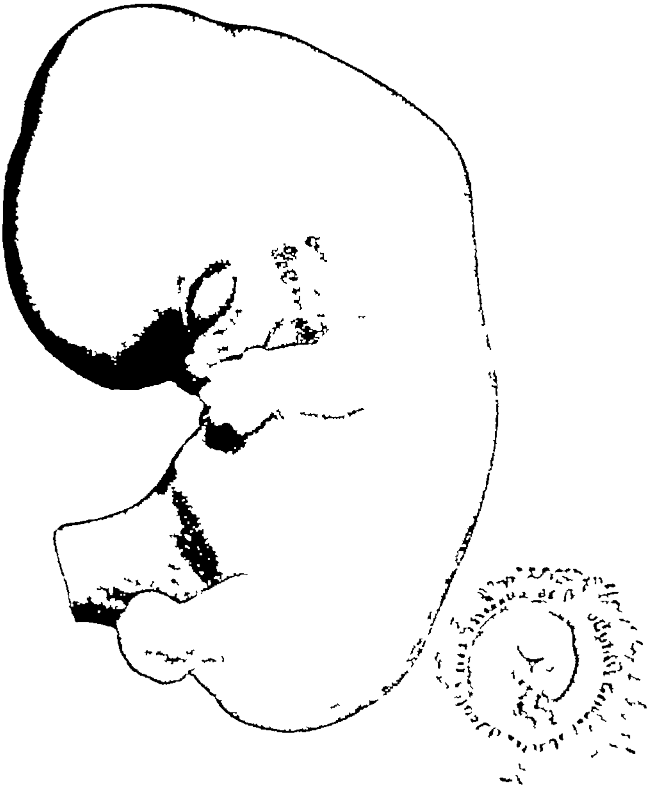

Fig 14 B Human embryo of about seven weeks (17 mm) The head is lifting from the pericardium as the neck is forming the mandible is evident, and the pinna is moving toward its final location (By courtesy of the Carnegie Institution of Washington)

occipital artery coursing laterally in the path of the XIIth nerve is engaged by it, and so the XIIth nerve comes to hook around this vessel in the neck (see Fig 5) Sometimes the parent vessel, the occipital artery, is hooked around It also stands to reason that a second pouch and cleft vestige would course ventral to the IXth and Xth nerves A third pouch vestige would emerge caudal to the IXth nerve and ventral to the Xth nerve

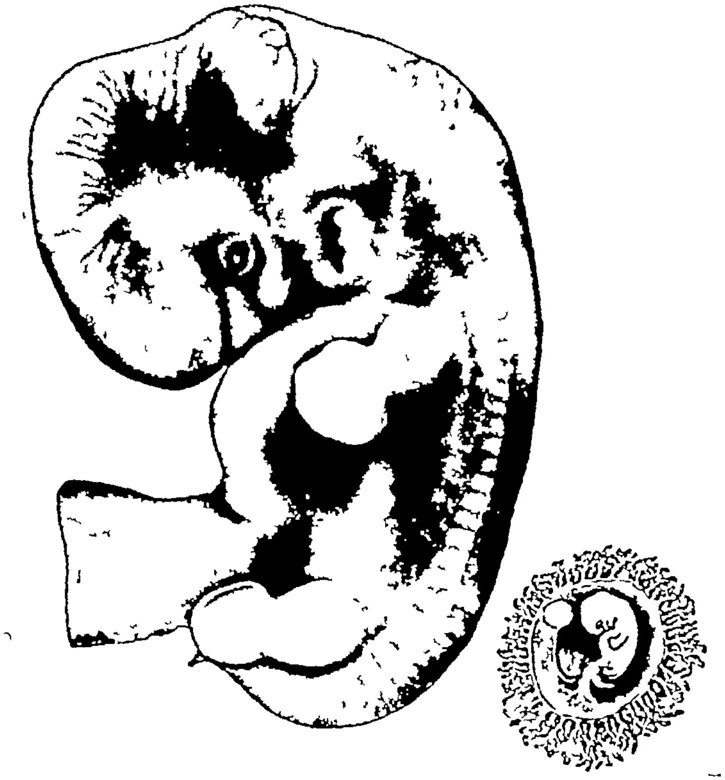

Fig 14 A. Human embryo a little over six weeks (14 mm) retouched photo The pinna is shown forming about the first groove posteriorly the head still remains curled over the pericardium the neck has not formed and the mandible has not grown sufficiently to force the pinna dorsally (From Patten[9] by courtesy of the Carnegie Institution of Washington)

sternomastoid is distinct in the caudal border of the sinus field (see Fig 15), also, coursing in this caudal boundary, but at a deeper level, and then turning to course ventrally to the sinus field in the epipericardial ridge, are the tongue muscles and the accompanying XIIth nerve It follows from this that any vestigial structure from the arch area must course ventral to the XIIth nerve, also, as the head grows away from the pericardium as the neck develops, and the XIIth nerve travels dorsally in the outer layer of the mesoderm of the body wall to its final position, it would engage any structures coursing laterally Frazer states that the sternomastoid branch of the ment condensation It is evident that the second groove at its ventral extremity is here in intimate relation with the clavicle and the infrahyoid and sternomastoid muscles The relationship is most pertinent (see Figs 15, 16) As ventral growth proceeds the infrahyoid muscles, fixed to the hyoid above and the clavicle below are drawn out on the ventral side The sternomastoid bounding the third arch caudally is a fixed structure behind The flexure line of the neck marks off the second and first arches cephalad, so that the third arch area by logical inference practically corresponds with the skin covering the carotid triangles Frazer does not contend that this correspondence to the carotid triangles is

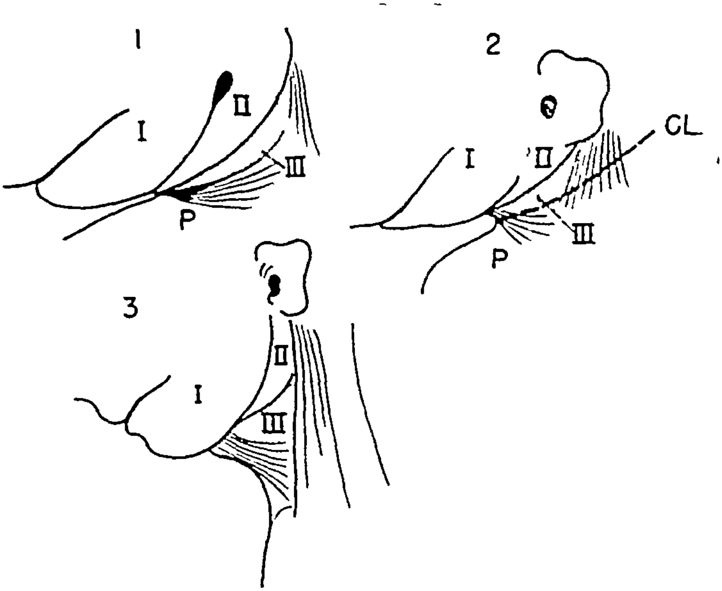

Fig 16 Three schemes to show the situation acquired by the third arch as the neck forms Cl gives the general position and line of the clavicle I II III branchial arches P pericardium

Note Visualize a persistent opening at the ventral end of the second groove in Scheme 1 then consider this opening trapped or maintaining its relation with the thoracic wall near the letter P As the infrahyoid muscles are drawn upward as the hyoid moves upward this opening is brought into relation with the anterior border of the sternomastoid the infrahyoid muscles rotate from a horizontal to a vertical position and the sternomastoid is drawn ventrally at its clavicular attachment —(From Frazer[4])

THE NECK FORMATION AND A THEORY EXPLAINING THE EXTERNAL OPENING OF FISTULAE NEAR THE STERNOCLAVICULAR JOINT

As noted above, the neck becomes evident as ventral growth becomes more active and separation from the pericardium is effected As this ventral growth starts, there are important changes rapidly taking place beneath the ventral extremities of the second and third arches in the epipericardial ridge and its environs The hyoid rudiment forms in the space between the ventral ends of the second and third arches The clavicular rudiment forms close by just caudal to the second groove (precursor to the transverse flexure line of the neck), where it is continuous with the episternal thickening ventral to the upper pericardium The infrahyoid muscles are in the epipericardial ridge here The sternomastoid muscle extends along the continuation of the caudal margin of the sinus field into the epipericardial ridge to contact the clavicular rudi-

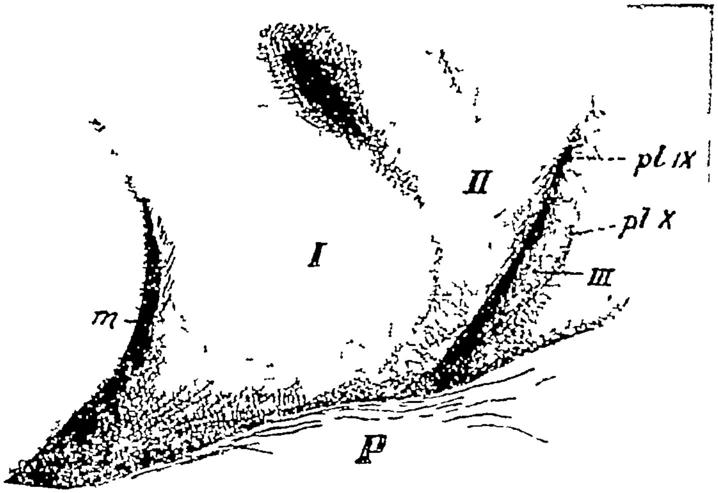

Fig 15 Left side of region in an embryo of 12 mm showing the structures behind the mouth m I II III branchial arches P pericardium ectodermal connections with placodal cysts indicated at pl IX, pl X The third arch is less prominent and is fading into the caudal boundary of the sinus field and epipericardial ridge with their contained sternomastoid muscle which serves to bound the anterior triangle of the neck posteriorly and inferiorly —(From Frazer[4])

is developed above and below the posterior extremity of the first (hyomandibular) branchial cleft from the first and second branchial arches respectively In Fig 14 it can be seen that the pinna when in its formative stages, before the neck is developed, is relatively ventral in location and close to the thoracic wall Arey[13] states that it persists in this location rarely, and when it does is in combination with agenesis of the mandible, with the mandible failing to force the ears laterally to the sides of the head It would seem, therefore, that with Frazer's demonstration of the persistence of the third arch on the neck, cartilaginous bars in this region would be more likely explained as due to a vestige of the third arch rather than a remnant of the pinna left behind Hyndman and Light[5] and Brown,[14] state that small bits of cartilage are often found at the external orifice of lateral fistulae These may be of second or third arch origin, and strengthen the case for branchial as against thymic duct origin

It can be seen from the above that branchial remnants can exist below the level of the hyoid A breakthrough in the third groove, as well as one from the second, could be related to the infrahyoid and sternomastoid muscles in the approximate region of the carotid triangles A fistula of third membrane breakthrough is primarily less likely from an embryological standpoint (see section on closing membranes), second, it would have to course posterior to the common-internal carotid axis and open internally in the pyriform fossa A breakthrough of the second closing membrane is more likely embryologically, and if it emerges in the ventral extremity of the second groove is closely related to the clavicle, infrahyoid and sternomastoid muscles (See Figs 15, 16) Its proximal relations would have to be either between the internal and external carotids or anterior to the carotids, and it would have to pass beneath the posterior belly of the digastric muscle, and open internally in the region from and including the tonsil fossa to the Eustachian orifice Perusal of the clinical literature indicates this latter set of relations holds for the usual lateral fistulae

Why is it that branchial cysts are found only in the upper

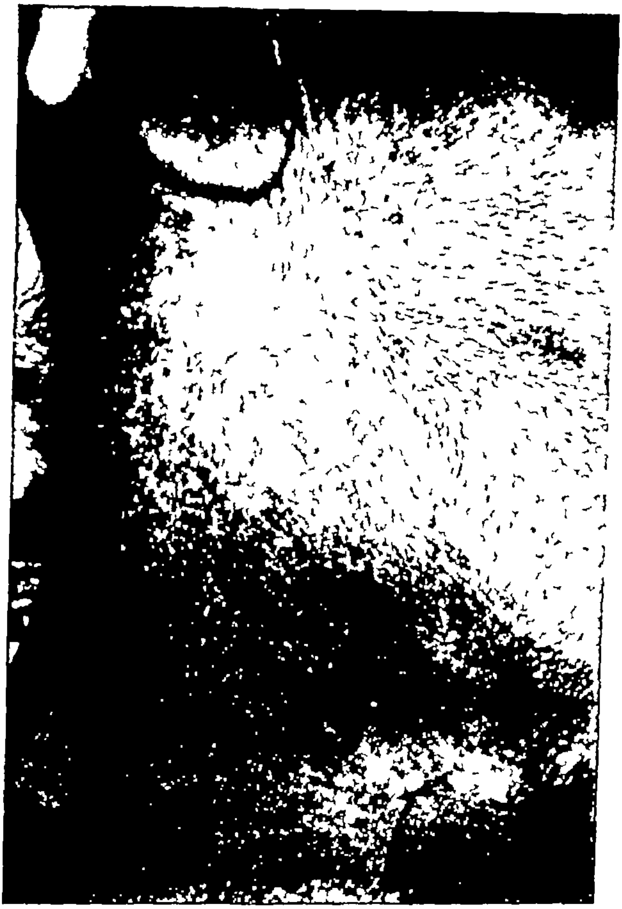

Fig 17 Photograph of a cervical cartilaginous bar Note that the bar is not at the anterior margin of the sternomastoid In this connection attention is called to Frazer's remark that the sternomastoid marks the posterior margin of the sinus field and that the third arch represented ectodermally on the neck is in the approximate region of the anterior triangle Also see under discussion of atypical external openings in Bailey H The Clinical Aspects of Branchial Fistulae British Journal of Surgery 21 173 1933

an exact one An external fistulous opening related to the posterior margin of the sternomastoid has been reported, in fact [22]

A cartilaginous bar in the general region of the carotid triangles, variously termed a cervical or auricular appendage, may well be a remnant of the cartilage of the third branchial arch Such a case is illustrated (see Fig 17) The pinna duct theory, as the thymic duct normally leaves the branchial area to course inferiorly.

How does Wenglowski explain the external opening of a fistula on the basis of thymic duct origin? A branchial fistula through the groove opens externally in the embryo, and if this condition persists there is a ready-made explanation for an external opening. Wenglowski states that fistulae open externally only by secondary suppuration. He reasons that only a thymic duct vestige would consistently open along the anterior border of the sternomastoid as this is related to its normal course, while a branchial fistula could just as easily open posteriorly in the neck, depending upon which haphazard direction the pus burrowed before pointing externally. While it is true that many fistulae show evidence of inflammation, I know of no other author who expressedly feels that this is the usual modus operandi of external opening of congenital fistulae.

How does Wenglowski get around the fact that the internal opening of lateral fistulae is in the second pouch area, let alone the course above the hyoid, which he accepts as of second arch origin in part? He concedes that the tonsil fossa proper is of second pouch origin. He argues, however, that fistulae opening in this region open not into the fossa proper but in relation to the palatoglossus muscle of the anterior pillar, which he claims is of third arch origin, innervated by the IXth nerve. The cases of Dowd,[15] Kleinert,[16] Blassingame,[17] and the author, however, exhibited openings within the tonsil fossa proper. Morris' Textbook of Anatomy states the palatoglossus muscle is innervated by the Xth nerve, the nerve of the fourth arch, while Gray's textbook states it is innervated by the XIth nerve; no mention is made of the IXth nerve.

Wenglowski decried Kanstanecki and Milecki,[3] who emphasized nerve and blood vessel relations as more significant than muscle relations. He stated that the development of vessels in this region was so confusing that no useful relation could be established. Frazer and Ward and Hendricks,[18] however, state that the relations to nerves and vessels are fixed, and third of the neck, while lateral cervical fistulae can open almost to the clavicle? I have presented a theory of the development of fistulae from a breakthrough of the second closing membrane at the time and place when the second cleft and the rudiments of the clavicle, infrahyoid and sternomastoid muscles are grouped close together It must be assumed that when an external opening occurs into the ectoderm at the base of the future neck, this opening is trapped in an area of relatively slow ectodermal expansion As the cephalic attachment in the region of the tonsil fossa grows away from this area in the ventral expansion, causing the formation of the neck, the fistulous tract is drawn out as are the infrahyoid muscles Where no caudal anchorage occurs, as in a branchial cyst or incomplete internal fistula, the vestige is carried upward or cephalad, maintaining its relations at the approximate hyoid level

REFUTATION OF THE THYMIC DUCT THEORY

Wenglowski[3] presented his thymic duct theory of the origin of lateral fistulae in 1913 Wenglowski stated that there was such a uniformity in lateral cervical fistulae that a common origin must exist He concluded, however, from his studies of human embryos that no vestige of the branchial arch apparatus could exist post-embryonally below the level of the inferior border of the hyoid bone This was based on his contention that the initial dorso-ventral relationship of the arches persisted, namely, the third and fourth arches remain dorsal to the second arch, and so no arch field derivative could persist caudally below the level of the second arch This has never been corroborated, and as has been shown by Frazer,[4] the third arch is represented on the neck in the region of the carotid triangles For this same reason, Wenglowski reasoned that any fistula of branchial origin could not turn down to reach a level below the level of the hyoid, but should course almost straight laterally to open in the region of the angle of the jaw Because most fistulae, however, do angle to course inferiorly and open on the neck, sometimes at the sterno-clavicular region, Wenglowski sought to find another explanation for fistulae, and came up with the thymic which he states shows close relationship to the thymus What does this imply as regards the usual lymphoid tissue in cysts above the hyoid level, which he will not contest as being branchial in origin? Lymphoid tissue is commonly associated with the pharynx

The author has encountered no clinical description of a complete fistula meeting the accepted criteria of third pharyngeal pouch origin, either thymogenic or branchiogenic This is confirmed by Dowd[15] quoting McKenty, Whitacre and Konig, and also by Taylor and Burwell[8] Rudberg reports a case in a 13-year-old girl presenting a swelling in the neck between the larynx and the carotid sheath which was found to lie in front of the sternomastoid with a small deeper ramification extending behind the common carotid, where it divided into ascending and descending branches The ascending branch ended blindly at the level of the carotid bifurcation, and the descending branch narrowed to a string ending in a terminal enlargement about a finger-breadth above the clavicle On microscopic examination the mass consisted of a few irregular cystic cavities lined with both flattened and stratified squamous epithelium, with considerable lymphoid tissue beside the cyst walls, and in this lymphoid tissue were a large number of small, rounded bodies resembling Hassall's corpuscles Rudberg stated most surgeons would consider this thymogenic, but, from its vessel relationship he considered it as a third branchial groove cyst with the additional presence of thymic tissue In the author's opinion, due to the absence of an external opening, this could well be a thymic duct vestige Certainly, the vascular relationship indicates third pouch origin, whether branchiogenic or thymogenic This case, however, is the exception that "proves the rule" Wenglowski developed his theory in explanation of the usual type of fistula, which as has been repeatedly demonstrated, opens in the region of the tonsil fossa, passes over the hyoid dorsal to the lesser cornu and passes either between the carotids or ventral to the carotid axis and opens externally near the sternoclavicular junction Rudberg's case meets the criteria of a third pouch-derived cyst and to prove it, exhibits the proper vessel relationship and demonstrates Hassall's corbarring vessel anomalies themselves, are the only constant guides as to origin of vestigial structures Wenglowski's paper erroneously states that the artery of the third arch is the external carotid

In further discussion Wenglowski argues that if a fistula is of branchial origin it should be lined by entodermal or columnar epithelium in its inner portion to correspond to the pharyngeal pouch portion, and by ectodermal or stratified squamous epithelium in its outer portion to correspond to the branchial groove, and that this arrangement does not occur, however, there are cases with just this arrangement, though they are not the rule Rudberg,[10] *e g*, cites several cases lined with stratified squamous epithelium which changed to ciliated columnar near the pharynx In fact, Rudberg found that squamous epithelium occurred in 90 per cent of cysts and fistulae, ciliated columnar, especially near the pharynx, in 8 per cent, and both types of epithelium in 2 per cent Carp and Stout[6] report branchial cysts with both types of epithelium side by side Wenglowski then found himself in the position of having to explain stratified squamous epithelium, supposedly indicating ectodermal origin, in thymic fistula and as noted in the section of "Fate of the Pharyngeal Pouches," explained it as based on contact with the cervical sinus ectoderm only in those cases where "ectodermal" epithelium occurred Actually, however, Maximow and Bloom[11] state that experimental studies of vertebrates show that many of the cells in the embryonic germ layers have no inherent specificity during early developmental stages, and that if they are moved from one place to another they will often develop in conformity with their new surroundings

Wenglowski has this to say about the presence of Hassall's corpuscles as evidence of thymic origin, and I translate as literally as possible "In cysts of the lower half of the neck are found clumps of flat epithelium which are similar to the Hassallian corpuscles" There is no specific case citation, nor is there reference to their ever having been found a complete fistula rather than a cystic structure, nor is there any statement as to the incidence of finding Hassall's corpuscles Much emphasis is placed on the wealth of lymphoid tissue felt not possible because of the thick layer of mesoderm intervening To him is ascribed the concept of the disappearance of the precervical sinus by fusion of the second arch with the thoracic wall, and the formation of the precervical duct as an explanation of the external opening of lateral fistulae Konstanecki and Milecki, in 1890, organized the literature to their time and were instrumental in discarding the schemes of Heusinger, Cusset and Bland-Sutton as not corresponding to anatomical facts They established the concept that the inner opening determines the origin of fistulae which is branchial, with the opening always in the inferior portion of the tonsillar fossa at the root of the tongue and so of second pouch origin

Wenglowski, in 1913, presented his thymic duct theory of the origin of lateral cervical fistulae with his major premise that no branchial vestige could remain beneath the level of the inferior margin of the hyoid bone His thymic duct theory has several weaknesses, as described His worthy contributions appear to be that he confirmed Hammar's (1902) findings that the points of contact of groove and pouch in the various closing membranes are not extensive and vary with the several membranes, even between sides of the same embryo, but that the most constant closing membrane, other than the first, is that of the second He also first described how the third arch was not obliterated in the precervical sinus

Frazer, in 1923 and 1926, demonstrated that the third arch not only was not obliterated in the precervical sinus, but also took part in the formation of the neck corresponding with the carotid triangles He also stated that the precervical sinus was not obliterated by a fusion of the second arch (Rabl) with the thoracic wall, but that the structures involved in the sinus are passively affected in the development and obliteration of the placodal ducts of the IXth and Xth cranial nerves He also demonstrated that all branchial vestiges must develop ventral or anterior to the XIIth nerve He also described the area from and including the tonsil fossa to the Eustachian orifice on the lateral pharyngeal wall as the postembryonal derivative of the ventral angle of the second lateral puscles If it exhibited Hassall's corpuscles and had vessel relations associated with accepted criteria of second pouch origin, then Wenglowski's theory would have some justification and embryologists would have to start over again

HISTORICAL SUMMARY [20,3,5,6]

Huncyowski, in 1789, probably reported the first cases of lateral cervical fistula The first accurate description of the branchial apparatus was in vertebrates by Rathke in 1825 He noted the resemblance of the branchial clefts to the gill apparatus of sharks but discarded any association phylogenetically Ascherson, in 1832, distinguished between median and lateral fistulae, and first associated lateral cervical fistulae with incomplete closure of the branchial clefts Cysts were included as branchial derivatives by Roser in 1859 Heusinger, in 1865 and 1876, reported that all fistulae opened internally near the base of the tongue and opened at various levels of the neck externally depending upon which branchial groove failed to close Cusset (1877) and Bland-Sutton (1895) presented different schema but based on identification of groove origin by level of external opening also

The next major contribution was by His, in 1881 He used human embryos and first used the more precise reconstruction method of studying them He described the closing membranes and noted their failure to break through normally, as in aquatic animals to form gill slits He described the precervical sinus and the triangular area ventral to the pharynx between the ends of the arches occupied by the pericardium, the mesobranchial field of His The prefix "pre-" in the term precervical sinus was intended to refer to a ventral orientation with regard to the neck (Rabl accused him of implying an oral orientation)

Rabl, in 1886 and 1907, described the closing membrane of the second pouch and groove as two layers of epithelium in contact and mentioned the proclivity for a breakthrough here to form a fistula He discounted a third membrane breakthrough possibility as a relation to the thymus or carotid body would have to exist A fourth membrane breakthrough was vestigeal fistulae and cysts below the mouth and ear regions Cysts and fistulae are of similar origin

2 The ventral angle of the second pouch is represented in the adult lateral pharynx as the region from and including the tonsil fossa to the Eustachian orifice A congenital fistula, with an internal opening anywhere in this region can be assumed to be of second pouch origin if it complies with nerve and vascular relationships If ever encountered, a third pouch fistula would open internally in the pyriform fossa and a fourth pouch fistula would open still lower, beneath the fold of the superior laryngeal nerve

3 A second pouch fistula courses over the hyoid, dorsal to the lesser cornu It then commonly passes between the internal and external carotid arteries, but may pass anterior or ventral to both An anterior course may be determined by preoperative X-ray of the tract filled with radio-opaque material An anterior course predicts a relatively simple operative procedure Embryological correlation of these variations is discussed

4 The relation to nerves and vessels is the determining factor in identifying the origin of a vestige, as well as the site of internal opening All branchial vestiges are found ventral to the XIIth nerve Second pouch fistulae should course ventral to the IXth and Xth nerves also

5 A third pouch vestigeal structure would have to open internally in the pyriform fossa, course beneath the hyoid and pass dorsal to the internal or common carotid artery No such relationship for a *complete* fistula has ever been reported A fourth pouch fistula would have to loop around the aorta on the left or the subclavian artery on the right, and again no such relationship has ever been reported

6 The thymic duct theory of Wenglowski as an explanation of the usual fistula under discussion is not in keeping with clinico-pathological and embryological facts

7 Embryologists list many possible sources of vestigeal structures,[21] and while they suggest the capability of producing vestigeal structures, only the second pouch and cleft pharyngeal pouch He would not conjecture as to the origin of vestiges in this region except in broad terms He mentioned the possibilities of the placodal ducts, as well as the grooves, under the heading of "abnormal persistence of normal states" or "delayed development" as well as "abnormal processes of development" Fistulae opening near the clavicle, he feels, could possibly derive by either method He apologizes for having ruined a duct system as part of the precervical sinus as a source of explanation

CASE REPORT

Mr J B W, white, age 33, was admitted Dec 22 1951 with a diagnosis of bleeding duodenal ulcer On routine physical examination the examining physician noted a small sinus above the sternal attachment of the sternomastoid which seemed to be attached to a cord under the skin, which ran cephalad On milking the cord the physician reported a clear mucus exuding from the sinus opening The patient was referred to the E N T clinic There was a history of drainage from the sinus opening as long as the patient could remember and the secretion was usually clear The patient does not recall ever having a sore throat A probe was passed to the upper level of the thyroid cartilage and passed beneath the sternomastoid at about its midpoint Probing caused coughing and a foreign body sensation in the throat at about the level of the superior border of the thyroid cartilage Lipiodol was instilled and X rays made These revealed a fistulous tract with no cystic enlargements in its pathway The tract passed over the hyoid just posterior to the lesser horn and then turned medially toward the pharynx On injecting the fistula with methylene blue, dye was seen to come from a large crypt in the upper pole of the right tonsil The tonsils were normal in appearance The fistulous tract was excised without difficulty via two step-ladder incisions The right tonsil was removed in the usual manner and the tonsil bed sutured There was no contact with the great vessels and the tract became quite thin as it approached the tonsil fossa Dissection was simple with no evidence of inflammatory reaction Post operative course was uneventful and a questionnaire three years later revealed the patient was asymptomatic as regards this lesion

The gross description was that of a tubular structure measuring 10 5 cm in length and varying in diameter from 4 to 6 mm An elliptical fragment of skin was noted attached to the specimen Microscopic description was as follows The tract is lined by stratified epithelium which does not show keratinization The epithelium is supported by connective tissue Definite smooth muscle structures are not seen There is very slight lymphocytic infiltration in this supporting connective tissue No structures similar to Hassall's corpuscles are seen Occasional fragments of salivary gland tissue are seen at various levels adjacent to the connective tissue This structure is surrounded by voluntary muscle and connective tissue Microscopic diagnosis was 'fistulous tract"

SUMMARY

1 All evidence points to the second closing membrane breakthrough as the most likely source of lateral cervical

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vestiges are significant clinically, with the exception of cartilaginous bars (see below)

8 The older concepts of the disappearance of the precervical sinus and the development of the neck appears to have been displaced by Frazer's work with human embryos The precervical sinus is passively affected in the development and obliteration of the adjacent placodal ducts (IX and X), with the sinus obliterating by a fusion from within toward the surface At no time is it represented by an ectodermal lined sac, all such simulation, according to Frazer and as confirmed by Garrett, is due to confusion with the ectodermal lined placodal ducts

9 The third arch is represented on the post-embryonic neck as the approximate region of the carotid triangles

10 The controversy over the significance of the relation of lateral vestiges to the stylopharyngeus muscle is critically discussed and a logical interpretation presented

11 A cartilaginous bar, also termed a cervical or auricular appendage, may well be a second or third branchial arch cartilage vestige unrelated to the pinna anlagen if found in the region of the carotid triangles

12 An explanation of why branchial cysts are confined to the upper third of the neck, while external or complete fistulae often open externally almost to the sternoclavicular junction is presented *

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*This last concept was originally presented to a weekly surgical staff meeting March 30 1955 Lyall and Stahl independently presented a similar hypothesis in a published paper (Lyall D and Stahl W M. Jr Lateral Cervical Cysts Sinuses and Fistulas of Congenital Origin Surg Gyn Obst 102(5) 417-434 May 1956)

1 Aid in the clinical localization of the site of nerve damage

2 Equate the degree of impaired chorda tympani nerve function with the degree of facial nerve paralysis

3 Aid in measuring and predicting, if possible, spontaneous recovery of the damaged facial nerve

With a view to accomplish these objectives, this study presents a technique for measuring the salivary secretion of the submaxillary salivary glands as an accurate index of motor function of the chorda tympani nerve

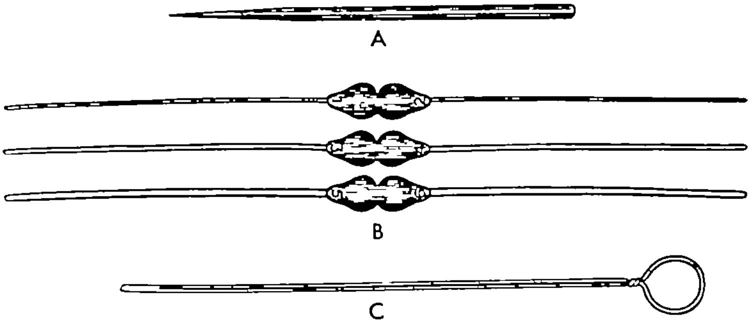

Fig 1 Apparatus for catheterization of the submaxillary salivary glands (Wharton's) ducts include A a lacrimal punctum director B Bowman's blunt-tipped probes C a section of polyethylene tubing PE No 60 and a fine wire stylet

TECHNIQUE

The equipment consists of a set of blunt-tipped Bowman lacrimal probes, a punctum director, polyethylene catheters No 60 (see Fig 1), and small Kahn type test tubes The patient is usually placed in the sitting position A solution of 10 per cent cocaine hydrochloride is applied topically to the orifice of each Wharton's duct This not only reduces the discomfort associated with dilation, but also makes the orifice visible by stimulating salivary flow Aseptic technique is used throughout the procedure

A lacrimal punctum director is inserted into the orifice of

SUBMAXILLARY SALIVARY FLOW: A TEST OF CHORDA TYMPANI NERVE FUNCTION AS AN AID IN DIAGNOSIS AND PROGNOSIS OF FACIAL NERVE PARALYSIS.*

JOHN E. MAGIELSKI, M.D.,
and
IRVING M. BLATT, M.D.,†
Ann Arbor, Mich.

Disturbances of taste and secretion of saliva are frequently associated with facial nerve paralysis of the peripheral type. The application of these phenomena in localization of the facial nerve lesion is well documented, but the accepted criteria and methods of testing these functions are often variable and unreliable. This is particularly true in testing for chorda tympani function by analysis of taste perception.

The accepted criterion of a functioning chorda tympani nerve is the ability to perceive taste on roughly the anterior two-thirds of the tongue on the corresponding side. In the process of testing, a patient, whose taste is found to be absent by one examiner, may have normal or subnormal taste when tested by another. Inadvertent withdrawal of the tongue results in quick perception by oral and posterior glossal taste buds; also, saliva coming in contact with the solution carries the test substance to the back of the mouth, which further diminishes the reliability of the taste observation.

Guided by the anatomical and physiological fact that facial nerve damage between the geniculate ganglion and the exit of the chorda tympani nerve from the middle ear is accompanied by impairment of chorda tympani nerve function, an attempt was made to find a more objective test which would serve to

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*From the Department of Otolaryngology, University of Michigan Medical School, Ann Arbor, Mich.

†Dr. Blatt's present address is Department of Otolaryngology, Wayne State College of Medicine, Detroit, Mich.

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After each Wharton's duct has been catheterized the patient is asked to suck on a slice of lemon for 60 seconds, during which time the output of saliva from each submaxillary gland is collected and measured in drops per minute (see Fig 2) An assistant collects from one side while the examiner collects from the other The procedure may be repeated for multiple sampling, after which the catheters are removed and discarded

MATERIAL FOR STUDY

We have presumed to add to the lengthy literature on chorda tympani and facial nerve neuropathy because similar patients have been previously studied by the subjective sense, taste Before presenting our observations it may be well to state something about control tests In the study of normal individuals between the ages of ten and sixty, the flow of saliva from each submaxillary gland simultaneously is practically of identical volume regardless of the type of stimulus used For the first five minutes, the quantity is identical, over a 30-minute period the variations between the two salivary glands is not more than 0 50 to 1 0 cc The volume of saliva produced by lemon stimulation is greater than by chewing paraffin, but in each instance the right submaxillary gland will secrete the same quantity of saliva as the left [2]

Taste testing for chorda tympani nerve function is also included in this study to illustrate the variations in acuity which produce equivocal results In testing taste, the tip of the tongue is covered with gauze and held by the examiner until the taste on the anterior two-thirds has been identified by the patient At this moment the patient points to one of six items written on a card "taste nothing, taste something but don't know what, bitter, sour, sweet, salty" In all observations, two minutes have been the upper limit for taste determinations in this study Substances not detected within this time usually will not be appreciated at all with any degree of reliability

The patients for study have been grouped into the following categories

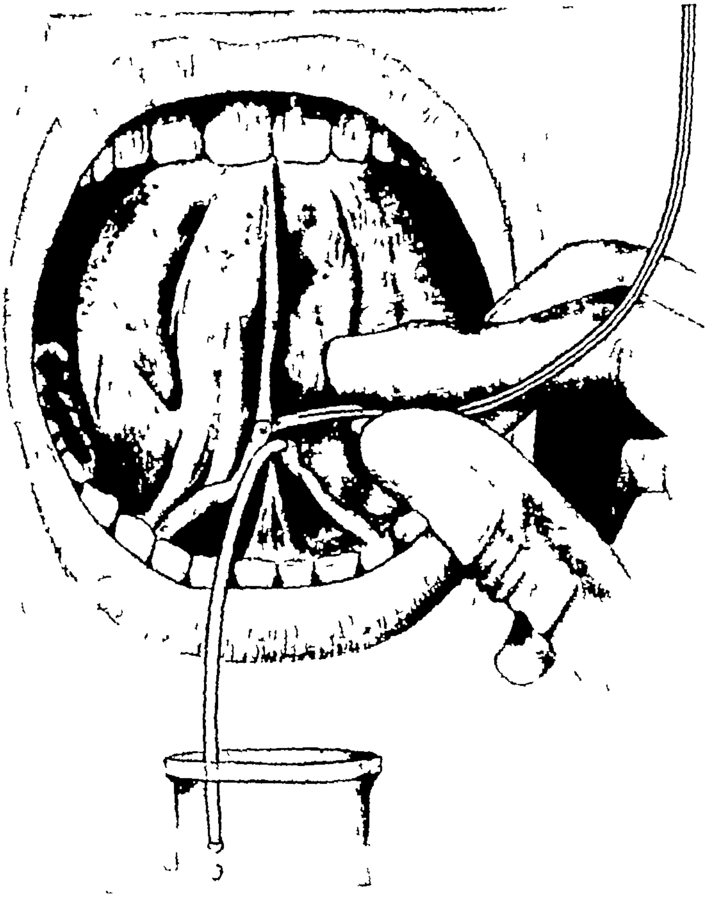

Fig 2 Catheterization of Wharton s duct and collection of submaxillary gland saliva An 8 to 10 cm section of polyethylene tubing is threaded onto a fine rigid wire stylet and is inserted into Wharton's duct for a distance of 3 to 4 cm The submaxillary gland saliva is collected in a small Kahn type test tube for each side while the patient sucks on a slice of lemon

Wharton's duct, after which dilation is accomplished with the Bowman probes, using sizes No 1 through No 4 A polyethylene catheter No 60 (sterilized in 1 500 aqueous benzalkonium chloride for at least 24 hours) is inserted into Wharton's duct for a distance of 3 to 4 cm This is best accomplished with the aid of a fine rigid wire stylet, onto which an 8 to 10 cm section of polythylene tubing is threaded[1] Precaution should be taken to avoid protrusion of the stylet beyond the open end of the polyethylene catheter

TASTE	Right (affected side) Seconds	Left. Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Taste Nothing	30
Sour	Taste Nothing	120
Salty	Taste Nothing	120
Bitter	120	120

SALIVA.	Right (affected side) Drops—Min	Left. Drops—Min
Lemon stimulation	0	32

At operation the chorda tympani nerve was found to be absent

At follow up examination one month later the following results were obtained

TASTE	Right (affected side) Seconds	Left. Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Taste Nothing	Not Recognized
Sour	Taste Nothing	Not Recognized
Salty	Taste Nothing	Not Recognized
Bitter	Taste Nothing	Not Recognized
Bitter	120	120

SALIVA.	Right (affected side) Drops—Min	Left. Drops—Min.
Lemon stimulation	0	42

DISCUSSION

Taste testing in these cases was equivocal In another patient in this group, the salivary flow on the affected side was reduced 50 per cent when compared with the normal side At operation, the chorda tympani was found imbedded in scar and granulation tissue In this particular patient preoperative testing of taste was highly equivocal, and no decision could be reached as to whether taste was present Thus partial function of the chorda tympani nerve may also be detected by comparing submaxillary salivary secretion from both glands

The first patient (C A) presented is characteristic of the individual who has an intact chorda tympani nerve prior to operation, which must necessarily be sacrificed in the performance of a radical mastoidectomy The paralytic effect of chorda tympani nerve section upon submaxillary salivary flow is illustrated

The second patient (G E) also demonstrates the difficulty

I Cases of chronic suppuration of the middle ear and mastoid

II Cases of facial paralysis due to idiopathic Bell's palsy

III Cases of facial paralysis associated with skull fractures including the temporal bone

IV Cases of facial paralysis associated with central nervous system disease

GROUP I CHRONIC SUPPURATION OF THE MIDDLE EAR AND MASTOID

Case 1 C A, No 859083, a 57 year-old mechanic was admitted on January 4, 1957, to University Hospital for a radical mastoidectomy There had been drainage from the right ear for approximately 50 years The patient was unaware of any taste deficiency On the day prior to operation the following results were obtained in tests for taste and submaxillary saliva

TASTE	Right (affected side) Seconds	Left Seconds
Water	Taste Nothing	Taste Nothing
Sweet (50% glucose)	30	30
Sour (vinegar)	30	30
Salty (Hypertonic saline)	30	30
Bitter (quinine)	30	30

SALIVA	Right (affected side) Drops—Min	Left Drops—Min
Lemon stimulation	42	41

At operation the chorda tympani nerve was found to be intact The nerve was sacrificed during the radical mastoidectomy There was no complaint of gustatory deficiency postoperatively Taste and saliva examinations on the fourth postoperative day and at the end of the second postoperative month were as follows

TASTE	Right (affected side) Seconds	Left Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Taste Nothing	30
Sour	Taste Nothing	30
Salty	Taste Nothing	30
Bitter	Taste Nothing	30

SALIVA	Right (affected side) Drops—Min	Left Drops—Min
Lemon stimulation	0	40

Case 2 G E No 809472 a 45 year-old salesman was operated upon at University Hospital on October 30 1956, for a chronically draining ear of about 25 years' duration There was no history of gustatory deficiency On the day prior to operation the following results were obtained in tests for taste and submaxillary saliva

type of facial paresis probably compatible with an hypertensive encephalopathy without other neurological deficit. Further examination noted that the patient could not smile on command or by emotional expression The hearing was normal Roentgenograms of the skull were normal The following results were obtained for taste and saliva tests

TASTE	Left (affected side) Seconds	Right Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Not Recognized	Not Recognized
Sour	Not Recognized	Not Recognized
Salty	Not Recognized	Not Recognized
Bitter	Not Recognized	Not Recognized
SALIVA	**Left (affected side) Drops—Min**	**Right Drops—Min**
Lemon stimulation	14	20

On the fourth hospital day there was a complete left peripheral facial paralysis without other neurological deficit Taste and saliva examination was as follows

TASTE	Left (affected side) Seconds	Right Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Taste Nothing	Not Recognized
Sour	Taste Nothing	Not Recognized
Salty	Taste Nothing	Not Recognized
Bitter	Taste Nothing	120
SALIVA	**Left (affected side) Drops—Min**	**Right Drops—Min**
Lemon stimulation	0	25

The patient was discharged on the fifth hospital day with the diagnosis of Bell's palsy One week later (13 days after the onset of the facial paralysis) there was partial motion of all the muscles of facial expression except forehead motion which was completely absent Taste and saliva test results were as follows

TASTE	Left (affected side) Seconds	Right Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Not Recognized	Not Recognized
Sour	Not Recognized	Not Recognized
Salty	Not Recognized	Not Recoginzed
Bitter	Not Recognized	Not Recognized
SALIVA	**Left (affected side) Drops—Min**	**Right Drops—Min**
Lemon stimulation	15	30

Eight weeks after the onset of facial paralysis there was complete return of function The results of taste examination were identical to those of the first test Submaxillary saliva examination results were as follows

SALIVA	Left (affected side) Drops—Min	Right Drops—Min
Lemon stimulation	50	49

encountered in eliciting a consistent response on the normal side It is of interest to note the reaction to bitter (quinine) in both cases The delay in identifying bitter taste in the second patient probably indicates that the test solution had travelled to the posterior one-third of the tongue, where practically all the gustatory receptors for bitter taste are located That there was no complaint of gustatory deficiency after recent complete removal of the chorda tympani nerve (Case 1) and after long term destruction of it (Case 2) appears to substantiate the observation of Crosby[3] She states that although modalities of taste can be recognized at subcortical levels, an individual's higher (cortical) centers are usually not concerned with the analysis of taste impressions from a specific geographical area on the tongue or palate, rather, the combination of taste, smell and texture, experienced during eating, are cortical associations which are acquired during the individual's own experience If a disturbance of taste does exist, the difficulty in localization may cause the patient to become confused and thus complain that a portion of the tongue feels "numb"

The second patient (G E) demonstrates the loss of chorda tympani function in long standing middle ear suppuration There is no flow of saliva by reflex chemical stimulation (sucking a lemon) preoperatively and postoperatively This phenomenon, observed in 11 similar patients in this Clinic, challenges the concept of reflex formation of saliva in the absence of secretory (motor) innervation—the so-called paralytic secretion of saliva In this instance absence of salivary flow exists after possibly two decades of chorda tympani destruction[1]

GROUP II FACIAL PARALYSIS DUE TO IDIOPATHIC BELL'S PALSY

Case 1 H W No 37565, a 53 year-old telephone lineman, was admitted to St Joseph Mercy Hospital on February 15 1956 because of inability to close the left eye and weakness of the left corner of the mouth for 24 hours On the day prior to admission the patient had been working in the rain

Physical examination revealed a blood pressure of 180/100 (RAR) the patient could not move the corner of the mouth or wrinkle the left side of the nose The left eye could be partially closed, there was no difficulty in wrinkling the forehead

The neurological consultant felt that the patient exhibited a central

TASTE	Right (affected side) Seconds	Left Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Taste Nothing	30
Sour	Taste Nothing	Instantly
Salty	Taste Nothing	Instantly
Bitter	Taste Nothing	Instantly

SALIVA	Right (affected side) Drops—Min	Left Drops—Min
Lemon stimulation	9	35

On May 15 1956 five days later there was no change in the facial paralysis The following results were obtained for taste and saliva tests

TASTE	Right (affected side) Seconds	Left Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Not Recognized	Instantly
Sour	Not Recognized	Instantly
Salty	Not Recognized	Instantly
Bitter	120	Instantly

SALIVA	Right (affected side) Drops—Min	Left Drops—Min
Lemon stimulation	28	40

Eighteen days later the patient showed considerable return of facial nerve function Only the frontalis muscle showed minimal activity Tests for taste and saliva were as follows

TASTE	Right (affected side) Seconds	Left Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Not Recognized	Instantly
Sour	Not Recognized	Instantly
Salty	Not Recognized	Instantly
Bitter	Not Recognized	Instantly

SALIVA	Right (affected side) Drops—Min	Left Drops—min
Lemon stimulation	37	40

Twenty four days after the onset of facial paralysis there was complete return of facial movement

Case 4 E T No 820213 a 48 year old colored housewife complained of inability to move the right side of the face for the past 24 hours Physical examination on August 18 1955 revealed a complete right peripheral type of facial paralysis without other neurological deficit. Otologic testing showed normal hearing The tuning fork and Tschiassny stethoscope tests for phonophobia were positive in the right ear The following results were obtained for taste and saliva tests

TASTE	Right (affected side) Seconds	Left Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Taste Nothing	Instantly
Sour	Taste Nothing	Instantly
Salty	Taste Nothing	Instantly
Bitter	30	Instantly

Case 2 B L, No 805312, a 32 year old white housewife, suddenly developed weakness of the left corner *of the mouth during an upper* respiratory infection Twenty four hours after onset there was a complete left facial paralysis On February 15, 1955, two days after the onset, the patient visited the Otolaryngology Clinic at University Hospital She complained of a *deficiency of taste on the left side of the* tongue Loud noises had an "echoing quality," and she did not wish to listen to radio or television because the sound "hurt" her ears, particularly the left one The physical examination revealed a complete left peripheral type of *facial paralysis without other neurological deficit.* A pure tone audiogram showed normal hearing The tuning fork and Tschiassny stethoscope tests for phonophobia were positive in the left ear Roentgenograms of the mastoid bones revealed no abnormalities The *following results were obtained for taste and saliva tests*

TASTE	Left (affected side) Seconds	Right Seconds
Water	Taste Nothing	Not Recognized
Sweet	Not Recognized	Instantly
Sour	Not Recognized	Instantly
Salty	*Not Recognized*	*Instantly*
Bitter	Not Recognized	Instantly

SALIVA.	Left (affected side) Drops—Min	Right Drops—Min
Lemon stimulation	29	43

On the thirty fifth day after onset of facial paralysis, the patient showed virtually complete return of facial function except for a slight weakness of the forehead There were no complaints of phonophobia or gustatory deficiency The following results were obtained for taste and saliva tests

TASTE	Left (affected side) Seconds	Right. Seconds
Water	Recognized as Sweet	Taste Nothing
Sweet	30	Instantly
Sour	30	Instantly
Salty	"Sour or Bitter"	"Sour or Bitter"
Bitter	30	Instantly

SALIVA	Left (affected side) Drops—Min	Right Drops—Min
Lemon stimulation	56	54

Forty five days after onset of facial paralysis there was complete re*turn of facial movements*

Case 3 D S, No 41361 a 32 year old mechanic noted weakness of the right corner of the mouth on arising in the morning Twenty four hours later, on May 10 1956, there was tearing and difficulty in *closing the* right eye No gustatory deficiency was noted Physical examination revealed a complete right peripheral type of facial paralysis without other neurological deficiencies Otologic studies showed a conductive hearing loss of long standing compatible with clinical *otosclerosis* Roentgenograms of the mastoids revealed no abnormalities The following results were obtained for taste and saliva tests early in the course of facial paralysis, may be erroneously diagnosed as a central type of facial paralysis, however, submaxillary salivary testing of chorda tympani nerve function was helpful in differentiating central from the peripheral type of facial paralysis The fact that the chorda tympani nerve was impaired, though functioning, is evidence of a peripheral rather than a central lesion In this instance it was also apparent that the degree of impaired chorda tympani nerve function could be correlated with the degree of facial nerve paralysis In this instance the recovery of chorda tympani nerve function corresponds with facial nerve recovery

The last three patients of this group demonstrate the more common situation observed when the patient consults a physician for a condition which turns out to be a complete unilateral peripheral facial paralysis due to Bell's palsy It is of note that such a patient may demonstrate partial chorda tympani nerve activity by salivary testing, in the presence of a complete facial paralysis This observation suggests the possibility that the patient may be spared the sequelae of imperfect facial nerve recovery It may justify also the prediction of a favorable prognosis for spontaneous recovery from complete peripheral facial paralysis when it can be demonstrated that the chorda tympani nerve retains its function or rapidly becomes functional early in the course of Bell's palsy It would appear also that the involvement of the facial nerve, by whatever pathologic process in Bell's palsy, is not severe, if the chorda tympani nerve is partially spared Further study is necessary, however, if these assumptions are to be confirmed

The fourth patient (E T) demonstrates the sequelae of imperfect recovery and facial disfigurement The partial return of facial nerve and chorda tympani nerve function appears to correlate for a two-year period Since the rate of chorda tympani nerve recovery did not exceed that of the facial nerve, the prognosis for facial nerve repair, in retrospect, appears to have been poor

In this group of patients we note the variability and un-

SALIVA.	Right (affected side) Drops—Min	Left Drops—Min
Lemon stimulation	0	32

One month later, there was no improvement of the facial paralysis, and a lateral band tarsorrhaphy was performed for prevention of exposure keratitis Submaxillary salivary secretion tests revealed the following

SALIVA.	Right (affected side) Drops—Min	Left Drops—min
Lemon stimulation	0	40

The patient did not return until January, 1956, six months after onset of the facial paralysis At this time there was residual weakness of all the facial musculature on the right side The following tests were obtained for taste and saliva

TASTE	Right (affected side) Seconds	Left Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Not Recognized	Instantly
Sour	Not Recognized	Instantly
Salty	Not Recognized	Instantly
Bitter	60	Instantly

SALIVA	Right (affected side) Drops—Min	Left Drops—min
Lemon stimulation	19	42

The patient failed to appear at regular intervals and was not seen again until November, 1957, twenty seven months after onset of facial paralysis There was residual weakness of all the facial musculature but sufficient orbicularis oculis function to permit removal of the tarsorrhaphy The following results were obtained for taste and saliva tests

TASTE	Right (affected side) Seconds	Left Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Not Recognized	60
Sour	Not Recognized	Instantly
Salty	Not Recognized	Instantly
Bitter	60	Instantly

SALIVA.	Right (affected side) Drops—Min	Left Drops—min.
Lemon stimulation	13	35

DISCUSSION

Ten patients with Bell's palsy were studied in this investigation Four have been selected for presentation because they demonstrate certain refinements in diagnosis of facial nerve disease which heretofore have not been reported

The first patient (H W) presents the complete clinical picture of Bell's palsy from its inception Such a patient, seen

TASTE.	Right (affected side) Seconds	Left. Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Not Recognized	Instantly
Sour	Not Recognized	Instantly
Salty	Not Recognized	Instantly
Bitter	Not Recognized	Instantly

SALIVA	Right (affected side) Drops—Min	Left. Drops—Min
Lemon stimulation	20	65

Four months after injury the patient could close the right eye almost completely had good symmetry of the face in repose but the motion of the forehead was not noticeably improved Taste examination was the same as performed six weeks after injury Saliva examination was as follows

SALIVA.	Right (affected side) Drops—Min	Left. Drops—Min
Lemon stimulation	40	60

The patient subsequently left Michigan and has not been heard from since

Case 2 R.K No 805674 a 23 year-old male student was admitted to University Hospital on March 2 1955 because of a right facial nerve paresis On February 13, 1955 he had sustained a severe head injury with a linear fracture in the right temporal region from an automobile accident. Physical examination revealed a right sided weakness of all the facial muscles of expression the muscles of the forehead being the most severely impaired Otologic examination showed a hemotympanum and a conductive deafness A.D Roentgenograms revealed a fracture through the occipital bone occipito-temporal suture extending into the petrous portion of the temporal bone

Taste and saliva studies were as follows

TASTE	Right (affected side) Seconds	Left. Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Not Recognized	Instantly
Sour	120	Instantly
Salty	120	Instantly
Bitter	120	Instantly

SALIVA.	Right (affected side) Drops—Min	Left. Drops—Min
Lemon stimulation	32	58

Three weeks later facial mobility was much improved Taste examination was the same as performed previously Saliva examination was as follows

SALIVA.	Right (affected side) Drops—Min	Left Drops—Min
Lemon stimulation	86	105

Nine weeks after injury the return of facial movements was complete except for minimal frontalis weakness Taste and saliva studies were as follows reliability of taste testing in situations where there is impaired function of the chorda tympani nerve and facial nerve with subsequent spontaneous recovery of both In the third patient (D S) absence of taste was recorded in the presence of minimal but definite chorda tympani nerve activity as evidenced by submaxillary salivary flow on lemon stimulation

The fourth patient (E T) demonstrates another reason for the unreliability of taste testing on the anterior two-thirds of the tongue Engstrom and Wohlfart[4] state that in embryological development some fibers of the glossopharyngeal nerve may be drawn forward in the tongue and serve to conduct gustatory impulses in the absence of chorda tympani innervation This concept may be substantiated by the fact that bitter taste was the only definite gustatory experience unequivocally identified by this patient

GROUP III FACIAL PARALYSIS ASSOCIATED WITH SKULL FRACTURES

Case 1 J B , No 807846 a 20 year old student was admitted to University Hospital on April 8, 1955, for a severe head injury sustained in an automobile accident Physical examination revealed a complete right peripheral type of facial paralysis, conductive deafness and hemotympanum Roentgenograms revealed a slight tempor parietal fracture which extended into the petrous ridge toward the medial portion of the internal auditory canal Taste and saliva studies performed on April 18 1955 were as follows

TASTE	Right (affected side) Seconds	Left Seconds
Water	Taste Nothing	Taste Nothing
Sweet	Taste Nothing	Instantly
Sour	Taste Nothing	Instantly
Salty	Taste Nothing	Instantly
Bitter	Taste Nothing	Instantly

SALIVA	Right (affected side) Drops—Min	Left Drops—Min
Lemon stimulation	6	68

Three weeks after the accident a complete facial paralysis was still present. Taste examination was unchanged The submaxillary salivary studies were as follows

SALIVA	Right (affected side) Drops—Min	Left Drops—Min
Lemon stimulation	12	55

Six weeks after injury the hearing had returned to normal There was some motion of the forehead and the upper lip on the right side Taste and saliva studies were as follows

PRINCIPAL ORGANIC AND INORGANIC CONSTITUENTS OF *PURE* SUBMAXILLARY SALIVA
(LEMON STIMULATION)

STUDIES	Involved Side At Initial Visit	Involved Side At Recovery	Normal Side At Initial Visit	Normal Side At Recovery	Involved Side At Initial Visit	Involved Side At Recovery	Normal Side At Initial Visit	Normal Side At Recovery
pH	7.35	7.4	7.5	7.45	7.52	7.5	7.62	7.55
Amylase (units)	28,900	27,500	30,000	28,000	23,600	23,900	10,200	11,000
Protein (gm %)	0.11	0.04	0.2	0.18	0.012	0.009	0.16	0.15
Creatinine (mg %)	0.13	0.18	0.11	0.16	0.35	0.35	0.35	0.30
Uric Acid (mg %)	1.1	1.1	1.5	1.4	1.0	0.8	1.1	1.4
Sodium (meq/L)	16	24	21.8	26	22	27	32.9	36
Potassium (meq/L)	18	16	13.3	15	18	15	17	20
Chloride (meq/L)	14.3	18.1	28	31	trace	trace	22	21
Bicarbonate (as CO_2 c p in meq/L)	12.3	11.7	15	16.8	17.7	23.1	10.4	11.7
Calcium (mg %)	3.4	1.1	2.1	3.2	5.0	1.3	1.2	1.3
Phosphorus (mg %)	5.6	5.0	3.6	1.1	5.9	4.2	1.5	1.5
Total Volume Collected	18ml/15min	30ml/15min	28ml/15min	29ml/15min	22ml/15min	65ml/15min	63ml/15min	65ml/45min

PATIENT—B L Case 2 Group II

PATIENT—R K Case 2 Group III

Fig 3 The principal organic and inorganic constituents of pure submaxillary saliva from patients with peripheral facial paralysis associated with Bell's palsy and skull fractures who have recovered full facial nerve function spontaneously. The saliva was collected in individual containers via polyethylene catheters using lemon stimulation. The values obtained for the various constituents do not vary significantly in spite of the diminished volume of secretion thus demonstrating the all or none principle of nerve impulse transmission in the preganglionic parasympathetic fibers of the chorda tympani nerve

TASTE	Right (affected side) Seconds	Left Seconds
Water	Taste Nothing	Taste Nothing
Sweet	30	Instantly
Sour	30	Instantly
Salty	30	Instantly
Bitter	30	Instantly

SALIVA	Right (affected side) Drops—Min	Left Drops—Min
Lemon stimulation	70	72

Case 3 G S, No 854039, a 28 year-old welder, was transferred to University Hospital on October 3, 1956 On September 29, 1956, the patient was involved in an automobile accident and sustained a severe head injury and fractured mandible Physical examination revealed a complete right peripheral type of facial paralysis There was an extensive keratitis in the right eye A deformity of the superior portion of the external auditory canal prevented adequate visualization of the right tympanic membrane There was a conductive deafness on the right side Roentgenograms revealed a fracture of the mandible and a temporo parietal fracture with extension through the osseous right external auditory canal

Taste studies were omitted because of difficulty in protruding the tongue Submaxillary salivary examination was as follows

SALIVA	Right (affected side) Drops—Min	Left Drops—Min
Lemon stimulation	0	52

On October 8, 1956, decompression and neurolysis of the facial nerve was performed through a modified radical mastoidectomy approach Open reduction of the mandible with internal fixation and a lateral band tarsorrhaphy were subsequently performed

In February, 1957, four postoperative months, there was only minimal motion of the upper lip and nasal ala Salivary studies were as follows

SALIVA	Right (affected side) Drops—Min	Left Drops—Min
Lemon stimulation	9	65

In October 1957, one year after facial nerve decompression, minimal motion of the upper and lower lips and side of the nose was present Submaxillary salivary testing showed the following

SALIVA	Right (affected side) Drops—Min	Left Drops—min
Lemon stimulation	4	70

DISCUSSION

Six patients demonstrating facial nerve paralysis associated with skull and temporal bone fractures comprise this facial nerve trauma group Three cases have been described to deal of difficulty in moving the right corner of the mouth and that it seemed to droop.

Examination by the neurologists revealed a right-handed white female with a blood pressure of 150/100 (RAR). There was a lower facial paresis with poor delineation of the nasolabial fold. Minimal impairment of frontalis movement was also found. There was no other neurological deficit. The clinical impression was Bell's palsy.

Otolaryngological consultation on May 26, 1955 revealed only a lower facial paresis. Audiometric studies showed presbycusis. Roentgenograms of the skull were normal. Taste and saliva studies were as follows:

TASTE	Right (affected side) Seconds	Left Seconds
Water	Taste Nothing	Taste Nothing
Sweet	30	30
Sour	30	30
Salty	30	30
Bitter	30	30

SALIVA	Right (affected side) Drops—Min	Left Drops—Min
Lemon stimulation	20	20

Two weeks after onset of facial paresis there was minimal weakness of the right upper and lower lips. Taste and saliva studies revealed no change from similar testing performed on May 26, 1955.

Seven months after the patient's initial visit there was complete facial symmetry. Taste and saliva studies were consistent with those performed at the time of the first otolaryngological consultation. Final diagnosis: Mild hypertensive encephalopathy.

DISCUSSION

Three cases comprised this group: a patient with hypertensive encephalopathy, second, a patient with a nuclear lesion of the VIIth cranial nerve due to bulbar poliomyelitis, and a patient with a brain tumor in the floor of the fourth ventricle. Other patients with obvious central facial paralysis were studied for documentary purposes only. Indeed, the presence of equal submaxillary salivary flow on lemon stimulation indicating an intact chorda tympani nerve is another diagnostic aid in localizing a facial nerve lesion.

SUMMARY

A clinical test for chorda tympani nerve function by measuring submaxillary salivary secretion is presented as a practical office procedure. The technique of submaxillary (Wharton's) duct catheterization is described. It has been demon-

emphasize certain clinical and neuro-anatomical obser
pertaining to chorda tympani nerve testing

As noted in the Bell's palsy group, it appears that
of the facial nerve due to trauma may not be severe
chorda tympani nerve is partially spared (Obviously
temporal injury of the facial nerve will not involve the
tympani nerve) Since chorda tympani nerve func
present in the first (J B) and second (R K) pati
seemed in retrospect to indicate potential spontane
covery of good facial nerve function That recovery
the chorda tympani nerve and the facial nerve occurre
this out

The second patient (R K) illustrates the value of
tympani testing as an aid in localization of the facial
lesion in partial as well as complete facial paralysis

In the third patient (G S) the absence of chorda t
nerve, as well as facial nerve function, were factors in r
a decision for immediate decompression

Figure 3 is a quantitative tabulation of the principal o
and inorganic constituents of pure submaxillary sal
patients with Bell's palsy and facial paralysis associate
temporal bone fractures who have recovered full facial
function spontaneously The "all or none" principle of
impulse transmission in the preganglionic parasympa
fibers of the chorda tympani (the visceral motor fibe
sponsible for submaxillary salivary secretion) is demonst
It would appear from the three cases illustrated tha
constituents of pure submaxillary saliva, obtained by
ethylene catheterization of Wharton's ducts are not
changed quantitatively even though the salivary secret
quantitatively diminished

GROUP IV FACIAL APARALYSIS ASSOCIATED WITH CEN NERVOUS SYSTEM DISEASE

Report of Case M F, No 552842 a 58 year-old housewife visit
Neurology Clinic of University Hospital on May 24 1955 complain

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University Hospital, Ann Arbor, Mich

POST GRADUATE COURSES AT TEMPLE UNIVERSITY SCHOOL OF MEDICINE AND HOSPITAL

A Postgraduate Course in Bronchoesophagology, February 16th to 27th, 1959, and a Postgraduate Course in Laryngology and Laryngeal Surgery, April 13th to 24th, 1959, will be given by Temple University School of Medicine

These courses are to be given in the Department of Laryngology and Broncho-Esophagology, Temple University Medical Center, under the direction of Drs Chevalier L Jackson and Charles M Norris

The tuition fee for each course is $250 00 Application blanks and further information concerning dates of subsequent courses may be obtained by writing to Jackson-Research, Laboratory 604, Temple University Medical School, 3400 N Broad Street, Philadelphia 40, Pa strated that this procedure is a far more accurate index of chorda tympani nerve function than are tests for taste

Chorda tympani nerve function by measurements of submaxillary salivary gland secretion can serve as an aid in the clinical localization of facial nerve damage The peripheral and central types of facial paralysis can be determined when such differentiation is not obvious

In the peripheral type of facial paralysis, submaxillary salivary testing of chorda tympani nerve function appears to be a consistently reliable adjunct for intra and extra temporal localization of facial nerve injury

The degree of impaired chorda tympani function can be correlated with that of facial nerve paralysis when both are involved A good prognosis for spontaneous recovery might be predicted if it can be demonstrated that the chorda tympani nerve retains its function early or becomes functional rapidly in the course of Bell's palsy or traumatic facial nerve injury, however, further studies are necessary to substantiate this observation

The chorda tympani nerve contains the pre-ganglionic secretory fibers which activate the submaxillary ganglion and other parasympathetic ganglion cells imbedded in the substance of the submaxillary gland If the chorda tympani nerve is destroyed, no submaxillary salivary secretion occurs when the gland is stimulated by reflex chemical stimulation (eating) because the secretory fibers have been removed This observation challenges the concept of reflex formation of saliva in the absence of secretory innervation—the so-called paralytic secretion of saliva

Taste perception as an index of chorda tympani function is variable, and in many instances unreliable in testing the normal and abnormal sides of the tongue in conditions where there is simultaneous impaired function of the chorda tympani nerve and facial nerve *

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*Acknowledgement The authors are grateful to Dr Elizabeth C Crosby Professor of Anatomy University of Michigan for valuable service in this study

ETIOLOGY AND AGE

Of the 51 cases, 33 had a history of contact with lye, and eight with ingestion of commercial preparations under the trade name of Drano and Sani-Flush.[1] These commercial preparations are composed approximately of 95 per cent sodium and potassium hydroxide. Another which should be included in this group was from potash used to prepare a "hair oil mixture." Four cases were a result of drinking Lysol, two from household ammonia water, and one each from cresylic acid, phenol, and potassium permanganate (see Table I).

TABLE I

Agent	No. of Cases	Degree of Burn (Esophagoscopy) None	Mild (Erythema)	Moderate
Lye	33	21	5	7
Drano	7	4	2	1
Sani Flush	1		1	
Potash	1	1		
Lysol	4	4		
Ammonia Water	2	2		
Potass. Permanganate	1	1		
Phenol	1		1	
Cresylic Acid	1	1		
Total	51	34	9	8

Although evidence of mouth burns was present in all nine cases of chemical ingestion not in the alkali group, no burns were detected by esophagoscopy except one from phenol, which was classified as mild and required no treatment. This finding would agree with Owens,[1] in his report of 131 cases of chemical burns, in which he concluded that "ingestion of household chemicals, other than lye, in general use today need not receive the drastic treatment given the latter, as stricture formation from their ingestion is a rarity."

All 51 patients were five years of age, or under. Thirty-two were two years of age or under, and 19 were from three to five years of age (see Table II). This finding, in a hospital which admits patients to the age of 13, would indicate that most of these accidents occur in children who are not old enough to differentiate poisons from the usual food and

DIAGNOSIS AND MANAGEMENT OF CHEMICAL BURNS OF THE ESOPHAGUS*

LYLE G. WAGGONER, M.D.,

Detroit, Mich.

Ingestion of a corrosive substance creates a very difficult problem, both to the unfortunate patient and the attending physician, in treatment of the damaged esophagus. Solution of this problem has been sought since the time of Pliny, when it is recorded that the ashes of plants were treated with lime to produce sodium and potassium hydroxide for use in the manufacture of soap.

It is the purpose of this manuscript to illustrate how the treatment of many of the suspected cases of esophageal burns can easily be resolved, and to correlate a rational regimen for the management of all cases suspected of ingesting a corrosive chemical.

From January, 1952, to the present time esophagoscopy has been done on all patients presenting themselves at Children's Hospital of Michigan with a history of ingestion, or with evidence of fresh burns of the lips, tongue, mouth or pharynx, within the first ten days of contact with the chemical. This procedure was accomplished against moderate opposition from some of the endoscopic staff, who felt that esophagoscopic examination at this period carried considerable risk. It was also suggested that a damaging burn might escape notice through the esophagoscope. Both of these fears proved to be without foundation; therefore, the case study to be presented represents 51 patients admitted, for examination and treatment from January, 1952, through July, 1957, to a hospital which limits its admissions to children under 13 years of age.

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scarring from phenol, formaldehyde, ammonia water, Lysol, sulfuric acid, nitric acid, lactic acid, potassium permanganate, iodine and bichloride of mercury, but it is admitted that these do not usually cause strictures

Alkalies are the most destructive because of their ability to penetrate deeply into the layers of the esophagus to produce a liquifying necrosis Acids cause less destruction because they cause a coagulation of the superficial layers, forming a firm eschar which limits penetration to the deeper layers Destruction of the stomach is apt to be much more significant from acids The others, such as Lysol, may produce a mucosal surface erythema or superficial esophagitis, but the healing is rapid without sufficient scar to form strictures, therefore, this discussion of pathologic changes in the esophagus will be limited to ingested caustics

The relationship between the depth of penetration of the lye, and its concentration, has been shown in experimental animals by Krey,[3] who examined the effects of a ten-minute contact of different strengths of sodium hydroxide on the rabbit's esophagus He found that a N-solution (3 8 per cent) produced necrosis of the mucosa and submucosa, with some involvement of the inner longitudinal layers With a 3 N-solution (10 7 per cent), the necrosis extended to the circular muscle A 5 N-solution (16 4 per cent) involved the outer longitudinal muscle Necrosis extended throughout the esophageal wall with a 7 N-solution (22 5 per cent), and some effect occurred also to the periesophageal tissues These findings are significant when it is considered that ordinary washing powders may contain a concentration of caustic soda in excess of 7 N-solution, also, it is obvious that only small quantities of a concentrated caustic, mixed with the saliva and swallowed, may produce severe lesions of the esophagus Larger quantities of a more dilute solution, as in a suicidal or homicidal attempt, may cause not only severe trauma to the esophagus, but the stomach and duodenum are also in danger of involvement

The histopathologic tissue changes will depend upon the depth of penetration drink The seven-months-old baby was accidentally given phenol, which had been used as a toothache remedy by the family Another chewed a potassium permanganate tablet mistaken for candy Some ate from cans of lye crystals left open on the floor Others drank a solution of lye from bottles

From these findings, it is obvious that most of these accidental burns are due to the careless accessibility of open cans of lye to children, the placing of caustics in containers used for food (cup, glass, or soda pop bottle), or medicine cabinet accidents Lye in solution is a whitish, cloudy mixture which can easily be mistaken for milk by a child

Holinger and Johnston,[2] in their study of 96 cases during a 13-year period, found in the five to ten year age group, one who drank lye on a "dare," and another who drank muriatic acid from a coke bottle In the 11 to 20 age group, all were females, most of whom drank a corrosive chemical because of disappointment in love Over age 20 were those with psychopathic personalities intent on suicide

TABLE II

Age	No of Cases
7 months to 2 years	32
3 years to 5 years	19
6 years to 12 years	0

All of the cases in the present study can be considered accidental, since they were age five or under, and a social service worker examined the homes and carefully questioned the parents when any possible suspicious circumstance was encountered In none was there found any evidence of homicidal intent

PATHOLOGY

As previously stated, lye in its pure form, or in the commercial products where it is present in high concentrations, is by far the most damaging agent In the present series, none of the other chemicals caused significant changes in the esophagus Other reports in the literature contain cases of

When healing is finally accomplished, a dense fibrous coat has replaced the submucosa and muscular layers, and the newly formed epithelium is of a low stratified type without glands This end-result consists of an esophageal lumen with many pockets and channels, or the lumen may be completely obliterated

3 A still deeper penetration will cause necrosis through the entire wall of the esophagus causing a periesophagitis, and may even result in perforation with mediastinitis, pericarditis, or broncho-esophageal fistula A burn of this severity may not allow the patient to live through the stages of contraction and stricture formation Blassingame, et al ,[5] list early deaths as being due to severe pulmonary edema from aspiration of lye solution, massive necrotizing esophagitis, or severe shock

SIGNS AND SYMPTOMS

Marked edema and redness is evident immediately on the parts contacted by the corrosive The lower lip is usually involved to the greatest degree, with the mouth, tongue and pharynx being involved to a lesser extent A white membrane forms very rapidly in the more severely burned areas Immediate dysphagia occurs, accompanied by profuse salivation, which lasts from two or three days to a week.

DIAGNOSIS

Every patient with a history of ingestion, or evidence exhibited by burns of the lips, mouth, or pharynx from contact with a corrosive, must be considered to have an esophageal burn until proven otherwise A dilute solution may not show mouth burns, because of an extra heavy coating of mucous and saliva at the time of the ingestion, but still cause damage to the delicate esophageal membrane, therefore, suspicion of a burn of the esophagus should be aroused on history alone It was felt by the author that many of these patients with presumptive evidence of ingestion of a corrosive, did not suffer significant esophageal damage, and for this reason the 51 patients included in this study were esophagoscoped

1 A superficial burn may be represented by only a surface erythema, or there may be destruction of areas of surface mucosa without damage to the deeper tissues These areas will heal without scar formation, and there need be no fear of a stricture

2 A deeper burn will penetrate the submucosal and muscular layers, causing a desquamation of the mucosa, leaving these underlying layers exposed Belinoff[4] divided the course of this degree burn into the four stages of necrosis, ulceration, granulation, and scar formation, from observations on the experimentally-burned dog's esophagus The tissue cells of the submucosal coats are destroyed by coagulation of the intracellular proteins, and an intense inflammatory reaction is set up All layers of the esophagus have become involved in this acute inflammation during the first week, and the organ becomes semi-rigid The inflammation also involves the myenteric plexus of nerves, including both Meisner's and Auerbach's, so that both the muscles and nerves are involved in the degenerative process During this stage, the patient is seriously ill and is frequently unable to swallow his own saliva

Following this, new blood vessels begin to form with the proliferation of numerous fibroblasts By the end of the second week, collagen fibers have been laid down by the fibroblasts to fill the defect Extensive granulations form with new blood vessels freely ramifying through this newly formed connective tissue At this time, the swallowing function returns approximately to normal, and the patient may be mistakenly believed to be out of trouble

Beginning about the third week, the collagen fibers begin to contract Adhesions, forming between the granulating areas, form bands and pockets with gradual narrowing of the esophagus As this contraction continues over a period of several months, the return of dysphagia may be apparent only in a change of the patient's eating habits, he will eat fewer solids, washing down each mouthful with water or milk, and he will learn to gag himself to raise food when it becomes impacted has been done in most cases since the beginning of the study in 1952, by repeated barium examinations, and none to the present time has shown evidence of esophageal narrowing. If any of these patients should develop dysphagia in the future, it is safe to assume that the narrowing would be of the semi-lunar or "shelf type," which would respond readily to a few dilatations.

It is also demonstrated in Table III that the long prevalent assumption that lye burns of the lips, tongue, mouth and pharynx usually infer esophageal damage is false, since only eight out of 43 patients were found to have burns of the esophagus requiring treatment. These findings are even more startling than those of Cody[11] who reports a series of 23 cases of mouth burns in which only 12 demonstrated esophageal pathology. From these data it is obvious that a false impression may have been presented by many of the reports in the literature of the prevention of stricture formation by early dilatation, since a large percentage of these patients undoubtedly had no esophageal damage at the beginning.

The findings in this case study would agree with Stumboff,[12] who asserts that esophagoscopy can be safely performed during the first stage of an essophageal burn "because the wall of the esophagus is covered with a thick membrane," and he doesn't feel that it is a safe procedure later during the presence of ulcerations and granulations. Daly[13] warns against esophagoscopy in the third week, when scar tissue contraction has begun. This belief is supported by one of our cases, when there were no complications following diagnostic esophagoscopy done eight days after the ingestion of lye, in which a severe burn was demonstrated, however, an ill-advised esophagosocpy and dilatation two weeks later resulted in perforation, followed the next day by air and exudate in the right pleural space and mediastinitis, and death within two days.

It has been our practice to use general anesthesia to reduce risk of trauma, and a careful examination of the hypopharynx is done before entering the esophagus. If a burn is found in this area, the esophagoscope is carefully introduced through from five to ten days after the accident It was felt that this was the *only way of making a positive diagnosis* of an esophageal burn, other than waiting for the formation of a stricture

Many authors have condemned early esophagoscopy because of the supposed hazard of perforation Others recommend delaying the procedure for two to three weeks (Jackson,[6] Woodward[7]) Lederer[8] advises that esophagoscopic examination is indicated only in "those patients who have no burns in the mouth or pharynx and when the agent is not known" Hanckel[9] states that esophagoscopy should be done in all cases, but not for several weeks after the burn has occurred in order to avoid perforation

Analysis of the 51 cases in this study has proven esophagoscopy to be a safe procedure, when done during the first five to ten days, *in that there were no complications from the* procedure in a single instance, and most of the examinations were done by the resident, in training, under competent staff supervision The value of such a procedure is shown in Table III, where 34 patients had no evidence of esophageal burn, nine had areas of mild erythema which required no treatment, and only eight demonstrated a burn requiring follow-up treatment *Many unnecessary and unpleasant treatments by* dilatation were thus avoided by 43 patients, much valuable time by the medical staff was preserved, and several extra days of expensive hospitalization and precious beds were saved

TABLE III

Physical Findings	No of Cases	Degree of Burn (Esophagoscopy) None	Mild (Erythema)	Moderate
Burns of Lip, Mouth, Tongue, or Pharynx	43	27	9	7
No Visible Burns External	8	7	0	1

It is granted that there has not been enough lapse of time in the more recent cases to be sure that the untreated cases may not develop a narrowing of the esophagus at a future date Stothers[10] mentions a case of sudden acute impaction occurring 40 years after the accident, however, follow-up extent and depth of penetration The resulting fibrosis of the gastric mucosa obliterates the gastric glands, altering digestion Varying degrees of pyloric stenosis will be caused by cicatricial penetrating burns

TREATMENT

As in causes of other serious accidents, treatment should begin with prevention The passage of the "Federal Caustic Act," requiring the use of conspicuous "Poison" labels, which was accomplished by years of work from the Committee on Lye Legislation of the Section on Laryngology of the American Medical Association, has reduced the incidence of lye burns to the esophagus by 90 per cent according to Jackson[6] The remaining 10 per cent would be greatly reduced if the public were educated to the seriousness of corrosive ingestion so that these preparations would not be brought into the home unless absolutely necessary, and any excess would be promptly discarded or made inaccessible to children The cases of suicidal intent cannot be reduced, of course, except by restriction of sale of these preparations to the public

For convenience, management of esophageal burns can be divided into immediate treatment, intermediate therapy, and the treatment of the formed stricture

Immediate Treatment

Attempt at neutralization is advocated by most authorities Administration of vinegar in one-half strength, dilute acetic acid (2 per cent), or orange juice, along with copious amounts of water, is recommended for ingested alkalies Sodium bicarbonate in water is suggested for neutralizing acids Kiviranta[16] demonstrated that antidotes have no value unless administered immediately, he found no evidence that attempts to neutralize after the first minute had any effect on the clinical course of the patient, and even taken within one minute it did not prevent injury to the tissues by a corrosive substance The thought has also been advanced that the chemical action of neutralization might produce enough heat even to increase the burn the cricopharyngeus and advance of the instrument is immediately halted at the first sign of damage except in the presence of only mucosal erythema In case of the latter, the examination is continued until signs of actual penetration are encountered

Under these circumstances, it is felt that the procedure carries little if any risk, while offering valuable information as

1 Proof of whether further treatment is necessary

2 Estimation of the length of time treatment dilatations will be necessary A complete circumferential burn will have to be dilated over a much longer period of time, if cure is possible, than one which involves only part of the circumference

3 Value of early bouginage can be more accurately evaluated

4 Prognosis as to whether dilatations will provide a cure A deep, ulcerated, cicatricial burn will probably form a stricture in spite of dilatations

Although diagnosis of stomach damage, resulting from the swallowing of a corrosive, is not included under the subject of this review, possibility of its occurrence must always be kept in mind McKibben and Lee[14] warn that pyloric stenosis has not only been reported in patients with esophageal stricture, but has occurred also in patients with no demonstrable esophageal lesion

A review of the literature back to 1882, by Gray and Holmes[15] in 1948, revealed 139 cases of pyloric stenosis following the ingestion of some corrosive Although alkalies will exert most of their damaging effect on the esophagus, and acids on the stomach, the swallowing of an alkali can cause severe damage to the stomach Conversely, acid ingestion can cause esophageal trauma, and in most cases where an acid causes an esophageal stricture, a stricture at the pylorus of the stomach will also occur As in the esophagus, the severity of stricture at the pylorus will depend on the was no difference in the amount of granulations if Cortisone administration was delayed over 48 hours after the injury

Rosenberg and associates[20] reported that large doses of Cortisone resulted in a remarkable decrease in the tendency towards fibrous stricture formation in lye burns of the rabbit's esophagus, but there was spontaneous perforation of the esophagus in five of the 44 rabbits under Cortisone, which they attributed to the antianabolic, antifibroplastic effects retarding the laying down of a granulation tissue barrier These experiments are paralleled by reported cases of exacerbation and perforation of existing peptic ulcers during treatment with Cortisone Weisskopf,[21] carrying out similar experiments on dogs, reported the formation of no strictures in the group treated with Cortisone, whereas all of the control animals living over 35 days developed strictures Eleven patients with presumptive evidence of esophageal lye burns (mouth burns and dysphagia) were given steroid therapy by Ray and Morgan[22] Of these, ten patients did not develop strictures, and one formed a clinical stricture after three months, the one failure was attributed to the Cortisone's not having been started until four days after the lye ingestion

From the preceding investigations, it is apparent that Cortisone therapy, if started within the second day of the accident, will greatly reduce the number of strictures resulting from ingested lye, but a note of caution must be inserted regarding the possibility of its use promoting a greater risk of esophageal perforation and mediastinal infections

The swallowing of a string, as soon as possible, during the acute phase is recommended by most authorities This helps to prevent complete atresia in severe cicatricial burns, and provides a guide for later endoscopic examination and dilation The use of an indwelling feeding tube is unwise, because of the danger of pulmonary complications and because of its acting as a foreign body to stimulate greater formation of granulations Daly[13] also suggests that it may delay the passage of food with the result that food particles may become enmeshed in the granulations, also causing foreign body reaction

Stomach lavage is contraindicated when the ingested agent is an alkali (Crowe[17]), because of the danger of further damage to the walls of the esophagus and stomach. When the agent is an acid, washing-out of the stomach might be of value in avoiding pyloric stricture.

Administration of olive oil and milk during the first 24 to 48 hours at frequent intervals, is generally accepted treatment of value. They have a soothing influence on the inflamed areas.

Since the patient will frequently refuse to swallow, even his own saliva, during the first two or three days, intravenous fluids may be indicated to prevent dehydration and to provide nourishment. Addition of vitamins *B* and *C* to these parenteral feedings may promote healing.

A bland soft or liquid diet can be given as soon as the patient will swallow, except in the very severe burns where perforation of the esophagus may be suspected.

Adequate antibiotic therapy should be started at once in the form of penicillin and streptomycin, or the "broad spectrum" variety. It was demonstrated by Bosher, Burford, and Ackerman,[18] in their experimentally produced lye burns of the esophagi of dogs, that there was evidence of bacterial invasion of the muscularis varying from actual phlegmon formation to localized intramural abscesses, within 48 hours, therefore, the amount of eventual scarring, and the danger of complications from immediate perforation, will be greatly lessened with the early institution of vigorous antibiotic therapy.

Cortisone administration during the acute phase has several enthusiatic supporters. Many experiments have been carried out on animals which demonstrate the potent inhibitory influence of Cortisone on the inflammatory response of tissue to injury. Spain, Molomert, and Haber,[19] in mice experiments, found scant collections of fibroblasts, insignificant collagen formation, and no new capillaries, if Cortisone was started within the first few hours of injury, however, there course of treatment, daily dilatations were again resumed. Each treatment was begun with a bougie two sizes smaller than the largest used in the preceding treatment. The largest bougie used in each treatment was left in place for as long as possible up to 30 minutes. Of the 41 patients treated by this method, only one developed a stricture, conversely, of 14 patients of their series who received no dilatations, six formed strictures. The safety of this method was demonstrated by no accidents or deaths occurring in the 41 patients so treated.

The rationale for treatment of esophageal burns by early dilatations is based on the supposition that contraction of the collagen fibers laid down in the damaged area, is prevented. This form of treatment has also been championed by Crowe,[27] Kernodle,[28] and Holinger.[29]

Other authors disagree with the management of esophageal burns by early dilatations. This is based on the belief that the esophagus should be put at complete rest during the inflamed period, and that early dilatation serves only to maintain the inflammatory state. Stumboff[12] recommends direct bouginage through the esophagoscope when the stricture starts to form on the third to the sixth week. Dilatations were started by Vinson[30] only after the lumen had contracted by scar tissue to a size that would not permit the free passage of fluids, his report included a high percentage of deaths, revealing the danger of vigorous dilatation of a contracted scar.

Belief that dilatations of any kind are useless, was expressed by Burford, et al.,[31] who felt that modern esophageal surgery had outmoded this form of treatment. They maintained that all established strictures of the esophagus were surgical problems.

Late Treatment

When a cicatricial stricture has formed, weighted bougies of the type used in early dilatations are not effective, although they may still be of value in the semi-lunar or "shelf type" of narrowing.

Blind bouginage, other than with the mercury or lead-filled

Intermediate Therapy

Since the burned esophagus tends to start contraction during the third week, prevention of a stricture becomes the main concern during this latent phase Supportive measures should be continued as outlined under immediate treatment In addition, the advisability of dilating the damaged esophagus, as soon as the patient is able to swallow, must be considered

Salzer[23] is credited with being the first to advocate early dilatations In 1920 he reported 12 cases in which dilatations had been started on the second to sixth day after ingestion of the corrosive

Attention was drawn to Salzer's report by Bokay,[24] in 1924, when he reported the use of early dilatations in 132 patients with excellent results in 117 Good results in 90 per cent of 180 patients was reported in 1934 by Salzer[25] with his method of early dilatations

In this country, Martin and Arena[26] reviewed the subject of lye ingestion and reported three cases of early dilatation in 1939

Early dilatations were begun, in 1924, by Gellis and Holt[27] in the Harriet Lane Home of the Johns Hopkins Hospital They reported on 110 children with a history of lye ingestion in 1942 Dilatations in 41 of these patients were started immediately if there was not great swelling of the fauces, and it was never postponed more than four days Bougies consisting of soft rubber catheters filled with lead shot were used from No 14 to 34 French Dilatations were started with a small size bougie and worked up until the largest size passed with difficulty No force was used in passing the bougie, and if evidence of bleeding appeared the treatment was discontinued for the day The amount of treatment required was found to vary with each patient, however, the usual schedule consisted of daily dilatations for two weeks, three times a week for the next two weeks, twice a week for two months, once a month for six months and two or three times a year for two or three years

If any increasing difficulty was encountered during the

4 Persistent ulceration for many weeks, as evidenced by blood streaking on the bougie

5 When the scarred esophagus cannot be dilated without danger of periesophagitis and mediastinitus

6 When cooperation of the patient cannot be obtained for the necessary regular dilatations because of a psychotic personality

Surgery of the esophagus has made great advances during the past 20 years, due to improved surgical techniques, greater knowledge of physiology concerning fluid and electrolyte balance, the great advances in anesthesiology, and the introduction of chemo- and antibiotic therapy

Many techniques have been developed for restoration of the normal swallowing mechanism in the damaged esophagus which cannot be rehabilitated by bouginage These methods can be conveniently divided into the antethoracic and intrathoracic approach

Antethoracic

In 1913 Torek[34] reported the first successful case of resection of the thoracic esophagus for carcinoma He brought the cervical stump of the esophagus out to the skin surface A long rubber tube was fixed in the gastrostomy opening, and the patient placed the other end into the cervical esophageal opening when he wished to swallow

A skin-lined tube connecting the cervical esophageal fistula with the gastrostomy opening was done on six patients by Yudin[34] in his report of 80 cases of surgical construction of the artificial esophagus He claimed a good functional result in these patients that survived, but one patient died between procedures, and two developed fatal peptic ulcers in the skin of the new esophagus This complication, plus the necessity of many surgical stages and prolonged hospitalization with a distasteful cosmetic result, has limited the use of this procedure

Subcutaneous jejunal substitution was used by Yudin in most of his cases, in conjunction with a cutaneous tube if type has long been condemned, because of the danger of hemorrhage, production of false passages, or perforation with mediastinitis Before other methods were available, Tucker[32] quotes Trousseau "Sooner or later, all cases of stricture of the esophagus die of the bougie"

If dilatation of the established stricture is considered to have a chance of success, the acceptable methods include

1 Direct dilatation through the esophagoscope, using Jackson dilators This method can be used in cases of a single stricture, but it is hazardous in the presence of multiple strictures

2 Olive-tipped bougies passed over a previously swallowed string eliminates the danger of the bougie entering a blind pouch This method does not require gastrostomy, and simplifies the task of the surgeon if *gastroesophageal anastomosis* is to be done later

3 Retrograde bouginage by the continuous string method of *Tucker*[32] *in gastrostomized patients*, is the safest *method* for extensive or multiple strictures

4 Pneumatic bougies placed under fluoroscopic control

It is generally accepted that dilatation of esophageal strictures should be continued until it becomes apparent that a functional esophagus cannot be obtained, or until it appears that further attempts at bouginage are dangerous Only then should a resort to surgical methods of repair be considered

The indications for abandoning dilatations and resorting to surgery are

1 Impermeable strictures *where there is a complete* stenosis and attempts to establish a lumen have failed

2 Scarring that has resulted *in pocketing* and marked irregularity or fistulas

3 Persistent poor response to dilatations where the lumen cannot be maintained at a functional size logically, to any form of external esophagoplasty as a method of restoring functional continuity of the upper alimentary tract"

Esophagogastric anastomosis may be the procedure of choice in strictures of the lower third of the esophagus As the level of the anastomosis goes beyond the level of the aortic arch, greater difficulty is encountered, especially with a previously gastrostomized scarred stomach, and the risk of an anastomotic leak is greatly increased

Fatti, et al,[11] reported 40 cases of esophagogastrostomy, all of which were anastomosed above the aortic arch There were 24 patients in whom restitution was complete, eight who required occasional bouginage, and eight who died after operation, a 20 per cent mortality They attributed the unsatisfactory results to the anastomosis being made at, or below the site of esophageal fibrosis The deaths occurred from peptic esophagitis and gastric ulceration with perforation

Intrathoracic esophagojejunostomy has been advocated by some authors for lesions involving the upper third of the esophagus Reinhoff[12] described this method of mobilization of the jejunum and anastomosis with the esophagus in 1946 The main disadvantage of this procedure is that the stomach, duodenum and upper jejunum are side-tracked by the food, and serve only to secrete juices into the intestinal tract

More recently, the ascending and transverse colon have been used in esophagocologastrostomy or pharyngocologastrostomy, and two cases were reported by Nardi[13] this year for repair of extensive lye strictures without resection of the esophagus Mahoney and Sherman[14] reported one case of total esophagoplasty, using intrathoracic right colon for carcinoma in 1954 This procedure has the advantage of the colon providing enough length so that the upper anastomosis can be made at the most optimal site, and all of the scarred area can be by-passed The colon also seems to have a higher resistance to the acid-peptic secretions of the stomach, as demonstrated by Dragstedt and Vaughan,[15] who found that a loop of colon transplanted to the stomach of a dog was the jejunum would not reach He feels that this is the procedure of choice, and he is joined in this belief by Finnerty,[15] however, the esthetic result of this procedure is also subject to criticism

Most surgeons at the present time feel that the antethoracic approach is obsolete in comparison with the improved methods of intrathoracic substitution

Intrathorac

Resection of the scarred area, and end-to-end anastomosis of the esophagus, can be done for the single short stricture of less than five cm Gross[36] in 1948 reported one successful case treated in this manner This type of repair is not frequently applicable, because cases severe enough to warrant surgical intervention usually have multiple strictures

Esophagogastrostomy, with or without resection of the damaged esophagus, has been very popular with many surgeons Biondi[37] is credited with doing the first studies for this procedure in 1895, but he reported difficulty with leakage, and frequent recurrence of stricture formation at the site of the anastomosis In their series of esophagogastrostomy in 52 dogs, Carter, et al ,[38] reported that no strictures formed if the end-to-side type of anastomosis was made, where one end of the esophagus was anastomosed either to the edges of the incision in the fundus of the stomach, or to the edge of a circular area excised from the fundus, they also reported an 89 per cent incidence of perforation at the line of anastomosis when no anchoring sutures were placed in the stomach or esophagus, and no incidence of perforations when both the stomach and esophagus were anchored in position

The first case of esophagogastrostomy found by this author, was that reported in 1935 by Decker,[39] done for carcinoma This procedure was championed by Sweet[40] in 1946, in his report of three successful cases done for esophageal stricture in which he states that, "in cases of intractable stricture of the esophagus resulting from chemical burns, an esophagectomy followed by a high intrathoracic esophagogastric anastomosis is superior anatomically, physiologically and psycho-the upper third with some delay of the barium Weekly dilatations with olive tipped bougies over a string were started Barium study of the esophagus 13 months later did not show any abnormality, although bouginage had been discontinued three months previously

A 16-month-old baby did not receive the advised follow-up treatment and developed a stricture requiring gastrostomy This patient is now under treatment with weekly retrograde bouginage She is currently dilated to a size-34 French This gastrostomy could probably have been avoided if early dilatations had been instituted

Another patient, who did not have follow-up treatment, became completely obstructed and a gastrostomy was done in another hospital When he came under our care, he had been fed through the gastrostomy for six months Numerous attempts to pass a string were unsuccessful External esophageal exploration was done by the surgical department, and a silk string was inserted, with the ends threaded into the mouth and out the gastrostomy fistula The patient expired 12 days after this procedure, with post-mortem findings of an esophagopleural fistula, left pyopneumothorax, pulmonary atelectasis, pneumonia, and barium in the lung and mediastinum

Comment Early treatment by bouginage might have rehabilitated this patient When attempts to pass a string failed, surgical reconstruction with one of the intrathoracic methods would have been preferable to the attempt that was made

The other patient of this series has been discussed previously He had no ill effects from diagnostic esophagoscopy done nine days after contact with lye, however, an ill-advised esophagoscopy done 27 days after the ingestion resulted in perforation and death in two days

Comment This case illustrates the safety of early esophagoscopy and the danger of the same procedure during the period of slough and scar tissue contraction If this patient had been started on dilatations with the mercury-filled bougies normal both macroscopically and microscopically after one year

It may not be practical to remove the scarred esophagus if there is considerable periesophageal fibrosis, since the planes are obliterated and severe bleeding may occur In such a case, the transected ends may be turned in to form a blind pouch Denton and Bradshaw[46] showed in experiments on nine dogs that the closed-off esophagus becomes a mucous filled cyst which produces no adverse effect The cyst is self-limited in size, since the pressure developed from within causes atrophy of the mucous glands If the esophagus is left *in situ* the vagi are not interrupted, and the annoying sequellae of gastric atony and retention are avoided, however, the possibility of carcinomatous development arising from the strictured site still remains Carver and associates[47] reported two such cases in their analysis of 233 patients with lye strictures, Cecil[48] reported two similar cases, and this author has had one in a patient that had undergone an esophagogastrostomy by the thoracic surgical department

When resection of the esophagus is done, it has been noted that the more rigorous the bouginage was pursued prior to surgery, the healthier the strictured portion appeared Cody[11] found cases in which there had been little or no effort at dilatation, to have the most reaction and infection

ANALYSIS OF CASE STUDY

In this series of 51 patients, with history of evidence of chemical ingestion, early diagnostic esophagoscopy revealed only eight that needed follow-up treatment

Four patients were treated by the "Salzer Method," approximately as outlined by Gellis and Holt[27] One had a complete circumferential burn of the upper third of the esophagus and the other three demonstrated linear burns All have been kept under observation for over two years, and none have developed signs of esophageal narrowing

One patient was not started on immediate bouginage, and an esophagogram one month later revealed narrowing in proaches are the most desirable, and of these, the use of the colon appears to offer the best chance of success

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following the first esophagoscopy, he could probably have been rehabilitated

It appears evident that the five patients who received adequate peroral bouginage will have a satisfactory result The three others, who should have had the same treatment, might well have had a similar outcome

The nine patients who revealed areas of mild erythema by early esophagoscopy, so far have shown no need for further treatment These, and the 34 others who had no evidence of esophageal damage, escaped the unpleasant ordeal of repeated bouginage, and none have returned with evidence of esophageal narrowing

CONCLUSIONS

1 Diagnostic esophagoscopy is a safe procedure in lye burns of the esophagus when done within five to ten days after the ingestion

2 Every patient with a suspected lye burn of the esophagus should be examined by esophagoscopy during this period to determine presence or absence of a burn

3 Severity of a burn, approximate length of time treatment will be necessary, and chances of ultimate cure can be determined by this initial esophagoscopy

4 Esophagoscopy is a less safe procedure during the third and fourth week after the ingestion of lye

5 Ingested chemicals, other than lye, do not ordinarily penetrate to the extent of causing ultimate stricture formation in the esophagus

6 Early dilatations, with weighted bougies, is preferable to delaying them until the stricture has formed

7 Whether the procedure of dilatations is of the early or late variety, it should be given adequate chance of success before the recommendation of surgical intervention is advised

8 When surgery becomes indicated, the intrathoracic ap-

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404 David Whitney Bldg

THE COLLEGE OF MEDICAL EVANGELISTS

A course in "Reconstructive Surgery of the Septum and External Nasal Pyramid" will be sponsored by the Departments of Otolaryngology of the College of Medical Evangelists School of Medicine and the University of Southern California School of Medicine, and will be given at White Memorial Hospital, Los Angeles, Calif The course will begin at 7 00 P M, January 6, 1959, and end 12 00 noon Friday, January 16 Dr Maurice Cottle will be the director All applications should be forwarded to Leland R House, M D, 1720 Brooklyn Avenue, Los Angeles 33, Calif

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lowing, gagging, or cough It should permit manipulation of the instrument at the carina and in the bronchi, and passage of suction tip and biopsy forceps without stimulation of reflex coughing To obviate personal bias the endoscopists in this study were unaware of the method of anesthetization employed

3 Subjective Evaluation by the Patient The induction of anesthesia should be accomplished with a minimum of discomfort to the patient because of compromising positions distasteful solution in the mouth, etc The anesthesia should be sufficiently complete, that the actual operation causes neither pain nor discomfort In addition to pain or discomfort, freedom from a degree of reaction to the anesthesia characterized by apprehension, a feeling of ill-being, palpitation, increased perspiration, and faintness are considered significant in influencing the patient's interpretation of the satisfactoriness of the anesthesia

METHOD

Observations were made upon 67 consecutive diagnostic bronchoscopic examinations Premedication consisted of phenobarbital, 0 1 h s , the evening before operation, and seconal 0 1, and morphine sulfate, 0 016, by hypo approximately one hour before operation The patients were anesthetized in a room adjoining the bronchoscopy clinic, and care was taken that the bronchoscopist did not ascertain the method used The two methods were varied indiscriminately The spray-drop method was used in 29 cases and the transtracheal in 36 In the transtracheal group 3 cc of 5 per cent cocaine were introduced in 21 cases, and the same amount of 10 per cent cocaine in 15 cases Two cases were eliminated from the scoring because bronchoscopy was not completed, due to anatomical difficulties in introducing the instrument at the time of the investigation

EVALUATION

Results were observed and tabulated at the time of introduction of the scope, and again during manipulation of the intrument deep within the trachea or bronchi Each case was scored, using the arbitrary standards of 5 for excellent

TOPICAL ANESTHESIA FOR BRONCHOSCOPY*

JAMES R MCKINNEY, M D ,†
McKinney, Tex

The advantages and disadvantages of various anesthetic agents for anesthesia in bronchoscopy have been extensively argued This study is concerned with the employment of a single drug (cocaine) in varying concentrations and by different techniques We have tried to evaluate as objectively as possible the relative merits of the transtracheal technique of anesthetization as compared with a spray or drop instillation of the agent In the first of these the anesthetic is introduced into the tracheal lumen by a syringe and needle passed through the skin of the neck and the crico-thyroid membrane In the spray and drop method the pharynx is sprayed, using an atomizer and 5 to 10 minutes later, a laryngeal mirror is introduced and anesthetic solution dripped through the glottis into the larynx and trachea

The evaluation is based upon three criteria

1 *Safety*—which implies avoidance of systemic reaction to the drug and accidents inherent to the technique itself It is recognized that various drugs have relative degrees of safety in this respect, but both the total amounts in milligrams and the concentrations of cocaine used in this study are considered to be within acceptable limits

2 *Objective Evaluation by Endoscopist* Anesthesia must be adequate to permit the introduction of the bronchoscope without causing discomfort or provoking troublesome swal-

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*This study was carried out under the direction of the late Dr James Carswell Jr Chief of Thoracic Surgery at the V A Hospital McKinney Texas The bronchoscopic procedures were performed by Drs Milton Hoffman and William Viar of that section and the anesthesias were administered by Drs Frank Davidson and James McKinney of the Section of Anesthesiology Observations of the factors chosen to satisfy the criteria were made as a joint effort by two or more of these physicians in each case The data were collected by Drs Davidson and McKinney The statical significance of the data was determined by Mr John Geers Clinical Psychologist attached to the Section of Anesthesiology

†Anesthesiology Section Veterans Administration Hospital McKinney Texas

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STATISTICAL ANALYSIS OF RESULTS

Introduction		Bronchoscopy
	Spray (N = 29)	
M = 21.79 S = 4.43 Sm = .84		M = 11.90 S = 2.70 Sm = .51
	Transtracheal 5 per cent (N = 22)	
M = 24.23 S = 1.28 Sm = .30		M = 13.77 S = 1.53 Sm = .33
	Transtracheal 10 per cent (N = 15)	
M = 23.93 S = 1.62 Sm = .44		M = 14.33 S = .99 Sm = .26
	Transtracheal (5 per cent + 10 per cent) (N = 37)	
M = 24.11 S = 1.45 Sm = .24		M = 14.00 S = 1.33 Sm = .22

t' Tests of Significance of Difference in Means

5% transtracheal introduction		M = 24.33	
Spray introduction		M = 21.79	
t = 2.77	d.f. = 49		Significant beyond .01 level
5% transtracheal bronchoscopy		M = 13.77	
Spray bronchoscopy		M = 11.90	
t = 3.07	d.f. = 49		Significant beyond .01 level
10% transtracheal introduction		M = 23.93	
Spray introduction		M = 21.79	
t = 2.25	d.f. = 42		Significant beyond .05 level
10% transtracheal bronchoscopy		M = 14.33	
Spray bronchoscopy		M = 11.90	
t = 4.26	d.f. = 42		Significant beyond .01 level
Combined transtracheal introduction		M = 24.11	
Spray introduction		M = 21.79	
t = 2.64	d.f. = 64		Significant beyond .02 level
Combined transtracheal bronchoscopy		M = 14.00	
Spray bronchoscopy		M = 11.90	
t = 3.75	d.f. = 64		Significant beyond .01 level
Transtracheal 5% introduction		M = 24.23	
Transtracheal 10% introduction		M = 23.93	
t = .57	d.f. = 35		Not significant
Transtracheal 5% bronchoscopy		M = 13.77	
Transtracheal 10% bronochoscopy		M = 14.33	
t = 1.33	d.f. = 35		Not significant

INTERPRETATION OF SIGNIFICANCE OF RESULTS

On the basis of this study it appears that the transtracheal technique is significantly superior to the spray and instillation technique for bronchoscopy, insofar as introduction of the in-

4 for good, 3 for fair, 2 for poor, and 1 for unsatisfactory, for each of these factors—swallowing, gagging, coughing, general comfort and general behavior during introduction of the bronchoscope Thus a perfect score for introduction was tabulated 5, 5, 5, 5, 5 with a total of 25, entirely unsatisfactory anesthesia for introduction resulted in a score of 1, 1, 1, 1, 1 with a total of 5

A second score was compiled for satisfactory results during manipulation of the instruments in the trachea, and based on the factors of coughing and general comfort and behavior These were similarly scored 5, 5, 5 for a total of 15 for entirely satisfactory, and 1, 1, 1 for a total of 3, if quite unsatisfactory

A summary of the scores follows

SUMMARY OF TRANSTRACHEAL VERSUS SPRAY TECHNIQUE

SPRAY			2 cc 5%			3 cc 10%		
Case	Introduction	Bronchoscopy	Case	Introduction	Bronchoscopy	Case	Introduction	Bronchoscopy
1	20	7	2	25	14	25	24	14
3	25	14	4	25	15	27	22	14
5	24	13	6	24	14	35	22	14
8	25	12	7	24	12	36	25	12
11	16	10	9	25	13	40	25	13
12	25	12	10	24	14	42	25	15
14	22	9	13	22	9	43	25	13
15	25	12	16	25	13	45	20	15
23	25	14	17	25	15	47	24	15
24	25	14	18	23	13	49	22	15
26	17	12	19	25	12	51	25	15
28	14	9	20	19	14	55	25	15
29	17	10	21	25	15	53	25	15
30	23	14	22	23	12	57	25	15
31	22	12	61	25	15	60	25	15
32	22	12	62	25	15			
33	25	12	63	25	15			
34	25	14	64	25	15			
37	21	12	65	25	15			
39	24	14	66	25	13			
41	25	11	67	24	15			
44	12	8						
46	25	14						
48	9	3						
52	25	15						
54	25	15						
56	19	15						
58	25	11						
59	25	15						

Cases 38 and 50 were discarded because of failure to introduce the bronchoscope for anatomical reasons

COMBINED NUTRITIONAL AND PSYCHOSOMATIC MANAGEMENT OF MUCOSAL DISEASE

The Stress Concept Applied to the Treatment of Ear, Nose, and Throat Diseases *

W D CURRIER, M D,

Pasadena, Calif

Dietary supplementation as part of the treatment of ear, nose and throat diseases has been so widely discussed in the literature that the subject seems well-nigh exhausted Convincing results were obtained with various dietary regimens and by the prescription of an appropriate vitamin therapy Clinical experience of this kind has been confirmed, not only by animal experiments but also by controlled tests in human volunteers, thus a number of deficiency diseases were recognized and standard treatment methods developed, but beyond these pathologic conditions there is a wide range of partial or potential deficiencies with ill-defined and variable signs and symptoms which may or may not respond to a change of diet or to vitamin therapy

Partial deficiencies or borderline states are by their very nature difficult to recognize Each case is different and occurs in an individual setting of physiologic and environmental conditions, thus generalizations are of doubtful value and little can be expected from use of the statistical method Animal experiments are at best suggestive, and the same holds true with regard to tests in volunteers or group observations Small wonder, then, that the field is rife with controversy and abounds with subjective statements from opposing camps Under these circumstances not much can be expected from a mere review of past observations, and the only hope for clarification of the issue lies in a fresh approach

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strument is concerned, and also for actual manipulation within the trachea and bronchi

The relative ease with which transtracheal anesthesia can be accomplished, and the rapidity with which anesthesia develops are further factors which, while outside the scope of this investigation, lend significant support to the conclusion of its superiority

It is of interest that the substitution of 10 per cent for 5 per cent cocaine in the transtracheal technique did not significantly improve the anesthesia

Since this investigation was carried out the technique has been modified to permit the use of smaller quantities of solution for the procedure, and in most cases it has been found that 2 cc of solution are adequate

INTERNATIONAL SYMPOSIUM ON RADIOLOGY IN OTOLARYNGOLOGY

On December 7 and 8, 1958, the Gruppo Otorinolaryngologica of the Alta Italia will sponsor an International Symposium on Radiology in Otolaryngology under the direction of Prof Luigi Pietrantoni, Direttore della Clinica dell' Universita de Milan, Prof Ardumo Ratti, Direttore dell' latitudo di Radiologica dell' Universita de Milan, and Honorary President Prof Felice Perussia For further information write the Secretary of the Symposium, Clinica Otorinolaryngologica dell' Universite di Milan, via Commenda 16, Italy the days of Hippocrates,[15] but it was Selye's contribution that he based his all-encompassing concept on findings in the field of hormonal interaction and tested it by exact laboratory experiments

This new approach has greatly stimulated research as well as the treatment of various diseases The stress concept was taken up by different medical specialties, foremost among them endocrinology, with psychosomatics running a close second, but there is no branch of medicine which has not profited by the discovery of stressors and the evaluation of stress-producing situations With ever more sensitive techniques of investigation the number of stress-producing agents and situations is constantly increasing

It would, however, seem that in paying attention to specialized applications of the stress concept Selye's basic idea of a unified theory of disease has been lost sight of In the light of his original plan the most remarkable discoveries in the field of hormonal interaction, or in any other of the specialties, are only means of clarifying the common basis of health and disease A frame of reference for hitherto unrelated biological events has been established This is important for the recognition of pathologic processes, but its significance does not end there It is only one step from a unified concept of disease to a unified concept of therapy By improving several seemingly unrelated functions we come closer to the ultimate objective of all medicine—to promote health The coordination of as yet separate methods or procedures into an integrated plan of treatment holds out promise of a much greater and more lasting therapeutic effect

Research and therapeutic experience have progressed far enough for such a unified approach to be applied in the management of common ear, nose, and throat diseases This can be best demonstrated with regard to the status of the mucous membranes of the ear and the respiratory passages, in health and disease

Nobody will underestimate the value of topical treatment, particularly chemo- and antibiotic therapy, in combating carriers of infection, but still more important are the natural to the problem of dietary deficiencies and nutritional supplementation

We might begin by considering the basic difference between pathology (morphology) and biochemistry, as pointed out by Williams[21] He remarked that the pathologist is often unable to distinguish morphologically between healthy cells and those which are deficient in some essential principle Pathology is limited to the study of end-products of disease processes, while the field of biochemistry is much larger, concerned as it is with all phases of life—not only the destructive ones This distinction is of greatest importance in modern therapy which is no longer restricted to the treatment of symptoms, but also aims at improving the patient's general health by attention to the underlying factors

What is health? If we consult the dictionaries we do not receive any real answer Webster defines health as "the state of being hale or sound in body, mind, or soul, especially freedom from physical disease or pain " Essentially the same information comes from medical dictionaries Blakiston, for instance, tells us that health is "that condition of bodily soundness in which the functions are performed normally, a state of well being and freedom from disease " The reference to "normal" functions is not much of a lead either Ivy,[8] in a very thoughtful paper on "What is Normal or Normality?" arrives at a description of the physiologically normal condition of the body "as that relatively steady state which results from well integrated functions supported by margins of safety in materials, structures and processes," but he adds immediately that this is not "a definite reference point from which to measure or with which to make a comparison Provocative as this physiological statement may be, it is certainly too vague to serve as a directive in the selection of therapy, and leaves us with only a general notion of what might be achieved

At this point the stress concept, as proposed by Selye, comes to our aid His definition gives the term "stress" a specific meaning[14] it is an attempt to arrive at a unified basis for various disease processes and their signs and symptoms Others before had tried such a unified approach, since the days of Hippocrates,[15] but it was Selye's contribution that he based his all-encompassing concept on findings in the field of hormonal interaction and tested it by exact laboratory experiments.

This new approach has greatly stimulated research as well as the treatment of various diseases. The stress concept was taken up by different medical specialties, foremost among them endocrinology, with psychosomatics running a close second, but there is no branch of medicine which has not profited by the discovery of stressors and the evaluation of stress-producing situations. With ever more sensitive techniques of investigation the number of stress-producing agents and situations is constantly increasing.

It would, however, seem that in paying attention to specialized applications of the stress concept Selye's basic idea of a unified theory of disease has been lost sight of. In the light of his original plan the most remarkable discoveries in the field of hormonal interaction, or in any other of the specialties, are only means of clarifying the common basis of health and disease. A frame of reference for hitherto unrelated biological events has been established. This is important for the recognition of pathologic processes, but its significance does not end there. It is only one step from a unified concept of disease to a unified concept of therapy. By improving several seemingly unrelated functions we come closer to the ultimate objective of all medicine—to promote health. The coordination of as yet separate methods or procedures into an integrated plan of treatment holds out promise of a much greater and more lasting therapeutic effect.

Research and therapeutic experience have progressed far enough for such a unified approach to be applied in the management of common ear, nose, and throat diseases. This can be best demonstrated with regard to the status of the mucous membranes of the ear and the respiratory passages, in health and disease.

Nobody will underestimate the value of topical treatment, particularly chemo- and antibiotic therapy, in combating carriers of infection, but still more important are the natural defenses of the mucous membrane, or to put it differently, its ability to deal with noxious agents of any kind. It has been convincingly shown that resistance to infection is lowered in stressful life situations.[7] Similarly endocrine and autonomic disturbances result in impairment of the protective functions of the mucous membrane.[8] Nutritional deficiencies not only interfere with smooth recovery from disease, but also change the microscopic structure of the mucous membrane and lower its ability to resist the inroads of stress.[1]

Therapy along any one of these lines at times produces spectacular results. Topical treatment is likely to afford immediate relief, endocrine therapy often leads to remarkable improvement, psychotherapy in one form or another may resolve the conflict-laden situation and thereby remove psychic stress, better nutrition not only increases all-around health but has also been found effective in lowering the incidence of upper respiratory disease.[10] The most promising approach, however, would seem to be a combination of these two last-named treatment methods with topical therapy to alleviate the immediate complaint.[4] It will be shown that dietary supplementation and psychotherapy are mutually supportive, one potentiating the beneficial effects of the other.[11,17,18]

Such an integrated plan of therapy amounts to a practical application of Selye's original concept of stress. The various stressors and stress-producing situations are interlinked, and by attacking several of them simultaneously it is possible to influence the overall reaction pattern of the patient. The whole is more than the sum-total of its parts.

Examples of how stressors and stress-producing situations are interlinked might easily be found in all fields of medicine and by critical evaluation of any therapeutic approach. Concentrating on dietary supplementation, there can be no doubt that this measure by itself is often highly effective.[2,3] Recently Watson, of W. C. Kalash Laboratories, Pasadena, Calif.,[19] obtained significant relief of mental symptoms by inclusive dietary supplementation, but dietary intake represents only one aspect in a much more comprehensive setting of internal and external conditions which determine the degree of being of the human organism. This has been well express by Dann and Darby, after surveying the many experiments and clinical observations regarding dietary deficiencies, they came to the conclusion that "the introduction and universal consumption of an ideal diet would not ensure abounding health, it would lay only one of the foundation stones on which such health might be based. A multitude of environmental factors, including as not the least important, the individual's reaction to his fellow members in human society, must be in correct adjustment before such health can ensue."

That diet should be evaluated in a setting of numerous conditions affecting the external and internal environment has been still more impressively pointed out by Kruse.[11] A clear distinction is made between "nutrition" as a bodily process and "diet," which is defined as a regimen of food supporting the bodily processes of nutrition. At first this may appear quite arbitrary, but we must remember that an increase of dietary intake is routinely prescribed under such conditions of special stress as growth, pregnancy, and hard labor.

The recognition of multiple stress-producing factors has not remained without impact on the treatment of nutritional disturbances. Jolliffe,[9] for instance, states that the successful treatment of vitamin deficiencies "involves treatment, and whenever possible, the elimination of the stress or conditioning factors. It involves symptomatic treatment, for a comfortable patient is of great aid to recovery. It finally involves nutritional therapy in sufficient amounts over a sufficient period of time to evoke maximal reversal of the nutritional syndrome."

A similar plan for a unified management of diseases involving the mucosa of ear and respiratory passages has proved very successful during the past few years. While a detailed report is reserved for a later communication, a few of the underlying principles will be discussed in the following.

According to Selye[16] "the primary object of the stress reaction is the maintenance of life and the re-establishment of normalcy during and following damage or functional activity."

Topical treatment, if necessary, combined with systemic therapy will as a rule result in repair of damage to the mucosa and re-establishment of its physiologic functions. This constitutes adequate management as long as we consider diseases of the mucosa of ear and respiratory passages as merely incidental, somewhat on the order of an unfortunate accident, but such a purely mechanistic view, attributing mucosal disease entirely to a foreign invader or to some kind of extraneous cause is no longer tenable. Mucosal disease occurs as a result of disproportion between insult and ability to deal with it. Merely topical treatment, even if combined with systemic support of local defense, leaves the underlying condition of failing resistance unchanged. The presenting acute illness is actually an exacerbation of a chronic condition of lowered physiologic responses, and it is due to this weakening of natural defenses that stressors which otherwise might have remained innocuous are able to produce disease.

As long as management is restricted to dealing with the acute episode, the patient is left in the same condition of disease proneness as before—we have ministered to disease but not to health; thus stress is regarded as an exclusively negative factor, or as Whitehorn[20] puts it, "stress has become a bad word." In a provocative paper on "The Healthful Benefits of Stress" he remarks that "perspectives have become so distorted at times that health efforts are aimed too sweepingly at the elimination of stress or anxiety." This represents the observation of a psychiatrist, but Whitehorn's advice that "doctors should think more discriminatingly about stress" applies equally to other branches of medicine.

What does all this mean in terms of the treatment of patients with diseases of the mucosa of ear and respiratory passages? Chemo- and antibiotic therapy is applied, and pain relieving drugs are administered, but management is not limited to these emergency measures, and a long-range program to build up the patient's resistance is immediately initiated. Of course, this is not possible in all cases, as many patients look upon their doctor simply as a trouble shooter; they take off a few minutes from the job, rushing into the office and rushing out again, expecting immediate relief and perhaps a pep talk, but are not open to further advice Many others, however, have begun to wonder why they catch cold so frequently or why they are bothered by recurrent attacks of ear, nose, and throat diseases Patients of this type are not satisfied with temporary relief, and expect the physician to do something about their disease proneness If approached with tact and sympathy they will cooperate in a long-range medical program Here the suggestion of a change of diet or dietary supplementation will fall on fertile soil, and the patient has no difficulty in understanding that such measures must be continued for some time before tangible results can be expected, but to suggest dietary therapy without having first gained the patient's confidence will rarely prove successful

By offering psychological support and prescribing dietary supplementation, an attempt is made to utilize the episode of acute disease as a starting point for improving the natural resistance of the body[12] At least potentially a new trend has been set up, a spiral toward health replacing the old spiral toward disease

Selye has drawn attention to the fact that any disease is a crisis involving the entire system Still more far-reaching is his distinction between various types of adaptation to threatening stimuli Even in adapting to a state of lowered resistance the human organism exhibits its fundamental tendency toward self-preservation The unified approach to therapy, combining topical, systemic, psychologic and dietary management is designed to improve adaptation to every kind of stimulus, with the ultimate aim of increasing overall fitness

SUMMARY

Re-study of clinical and experimental data in the light of Selye's stress concept has resulted in a new plan for the management of mucosal disease, particularly of ear and respiratory passages Multiple stress-producing factors call for a unified approach to therapy Topical and systemic medication is administered to afford immediate relief, but at the same time long-term management, combining psychologic support and dietary supplementation, is instituted to increase the patient's resistance to disease

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D E STAUNTON WISHART, M D ,

1888-1958

Dr D E Staunton Wishart died in Toronto in April, 1958, at the age of 69 He had been in ill-health for over a year, but carried on his work until a few months before his death

Dr Wishart was the son of Dr Gibb Wishart, who was a former professor of otolaryngology in the University of Toronto, so he was steeped in the traditions of medicine and the specialty in which he spent his medical career Educated at St Andrew's College and the University of Toronto, he received a B A degree from University College in 1909, and an M B from the Faculty of Medicine in 1915 He was an honor student throughout his medical school

During the first World War, Dr Wishart served in the Canadian Army Medical Corps and transferred to the Royal Army Medical Corps later He saw service in Gallipoli, Serbia, Macedonia and Palestine and was mentioned in dispatches at Salonika in 1917 On returning from overseas he took up the study of Otolaryngology and did post-graduate work in Boston, Philadelphia and Edinburgh, and on his return to Toronto was appointed to the staff of the Hospital for Sick Children He became chief of otolaryngology at the hospital and an assistant professor in the University, both of which positions he held until his retirement to private practice in 1953 He remained a graduate lecturer in the University

In 1939 Dr Wishart was appointed to the editorial staff of THE LARYNGOSCOPE and was assigned the subject of Rhinology in Children His annual reviews of the available literature on this subject were masterpieces He had an uncanny ability to get at the gist of a paper, and to cover it briefly, but thoroughly, in his Review

Dr Wishart was a member of the American Otological Society and was one of the few Canadians to become its President, which honor was conferred upon him in 1954 He was a former President of the Canadian Otolaryngological Society, a member of the American Laryngological Society, and the Royal Society of Medicine, London He delivered the Birkett Lecture in Montreal, in 1952, an outstanding honor in Canadian otolaryngology

One of Dr Wishart's chief interests was the study of deafness, and he did much research in the problems of hard-of-hearing children He founded the Clinic for the Prevention of Deafness, sponsored by the Atkinson Charitable Foundation at the Hospital for Sick Children, Toronto

Dr Wishart's main recreation interests were trout fishing golf, and his summer home at Georgian Bay among the Thirty Thousand Islands of Ontario He looked forward each year to his holiday there with his family

He is survived by his wife, two sons and a daughter

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REVIEW OF AVAILABLE LITERATURE ON THE LARYNX FOR 1957 *

Francis E LeJeune, M D ,
and
Mercer Lynch, M D ,
New Orleans, La

ANATOMY

Pichler and Gisel,[1] who worked on 100 dissections with a dissecting microscope, caution against accepting the presence of an extralaryngeal motor ramus posterior to the recurrent nerve They observed that this branch supplied the mucosa and anastomosed with the posterior segment of the superior laryngeal nerve In their dissections the main nerve branched endolaryngeally, and a definite abductor and adductor branch could not be demonstrated These observations do not coincide with those of King and Gregg, Rustad or Morris and, therefore, present food for thought, as any definite conclusion at this time would be premature

In a study of the recurrent laryngeal nerve in cats, Murray[2] noted that the nerve supplying the intrinsic muscles of the larynx in these animals has a unimodal fiber-sized distribution He was also able to show that there are few or no proprioceptor fibers in this nerve Probably one of his most interesting observations is that in the recurrent laryngeal nerve there is a variable number of fibers of extravagal origin

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*From the Department of Otorhinolaryngology Ochsner Clinic New Orleans La

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Caparosa and Zavatsky[3] describe the anatomy of the cricothyroid space, emphasizing the paucity of vessels and vital structures They recommend this space as a site for emergency tracheotomy in the full sense of the word emergency Whenever possible, this procedure should be followed by the classical tracheotomy within eight to ten hours to prevent development of stenosis Complications are listed, and steps to prevent these are described

Clader and co-authors[4] realized that a detailed knowledge of the surgical anatomy of the superior and inferior laryngeal nerves and their corresponding thyroid arteries is essential for surgeons who undertake surgical procedures upon the thyroid gland For this reason, they undertook to dissect, study and photograph the thyroid compartment of the anterior portion of the neck of 50 recently embalmed bodies Their findings are well tabulated, and the photographs clearly show the variations of the inferior laryngeal nerve, which in one case, divided into six branches Forty-three per cent of the specimens in this series had nerves with from two to six extra laryngeal branches Their conclusions pointed out that external division of the superior laryngeal nerve is often in danger during ligation of the superior thyroid artery There is no constant relationship between the inferior thyroid artery and the inferior laryngeal nerve This is an excellent article for quick review before thyroid surgery

Gregg[5] undertook a study of the extralaryngeal nerves for the purpose of facilitating recognition of these structures when doing thyroid surgery Some of the types of vocal cord paralysis produced in dogs help us to understand what may occur in patients undergoing thyroidectomy Gregg advocates routine dissection of the recurrent laryngeal nerve in all thyroidectomies Injury to the extralaryngeal nerves with resulting paralysis may be temporary or permanent depending upon factors as yet not explained

Negus,[6] in his inimitable and thorough way presents an interesting and enlightening article dealing with the history of man from the standpoint of the nose and larynx The ease of his style and the manner of writing belie the vast amount of work and energy represented in this concise article For one who is interested in research or as a reference article this concise manuscript is invaluable

PHYSIOLOGY

The Semon lecture on the physiology of phonation was delivered in 1956 by Portmann[7] In this interesting lecture Portmann discusses at length the myo-elastic, or tonic theory, and the clonic theory, however, there is little unanimity of acceptance of either theory Those interested in this subject should read his article, which also gives much consideration to the three levels of stimulation the cortex, the diencephalon and the medulla oblongata

In order to test a hypothesis on the origin of the vibrations of the vocal folds Van Den Berg and Spoor[8] made some simultaneous recordings on the electromyogram of the thyro-arytenoideus muscle and the sound curve in a patient who had a stoma just above the larynx and whose laryngeal muscles presented themselves directly Electrodes were placed, one in the thyro-arytenoideus muscle and the other near the arytenoid The vibrations were in agreement with the results noted by Trendelenburg and Wullstein Van Den Berg and Spoor state that the microphonic effect of the larynx will manifest itself in all the recordings of the potentials of a large region of the internal laryngeal muscles They believe that this is the explanation for the synchronism claimed between the potentials in the recurrent nerve and the sound pattern

In his usual interesting, thorough manner Negus[9] presents a comprehensive article on the mechanism of the larynx which leaves little to be desired He begins with the evolution of the larynx from the simple vertebrates to man In covering the phase of evolution, he describes the physiology and anatomy of various types of animals One of the important functions of the larynx, little considered, is the assistance in blood and circulation by pump action The other functions of the larynx are fully discussed It is concluded that phonation was developed secondarily Negus emphasizes the point that when dealing with the production of sound, the larynx of man follows the general physiologic principles applicable to other vertebrates and is not subject to mechanisms of purely human design

In a discussion of the theory of the nature of the vibrations of the vocal cords, Froeschels[10] states that until recently it was almost the general opinion that the vibrations of the vocal cords are initiated by the stream of air and that the swing back is due to the elasticity of the cords The function of the recurrent nerves was considered to be the innervation of the muscles that open and close the glottis The cranial branch of the pneumogastric nerve, according to the theory, innervates the cricothyroid muscle, thus helping to elongate the vocal cords This is called the myo-elastic or aerodynamic-muscular theory Husson's neuromuscular theory is new, according to it every vocal vibration is due to a single impulse from the recurrent nerve and not to air pressure This function of the recurrent nerve is from central stimulation with acoustic center regulating the pitch Froeschels questions Husson's theory, pointing out that many patients with bilateral abductor paralysis have excellent voices In some of these the recurrent nerve had been accidentally severed during operation Froeschels has been unable to accept the facts as described in the Husson theory, but he believes that this interesting theory should be studied further before it can be fully accepted

Floyd and co-workers[11] report their observations on numerous experiments on the mechanism of phonation There are two main theories the tonic and the clonic, and the advocates of each are staunch believers in the validity of their theory Floyd and associates describe the action of the intrinsic muscles of the larynx on the function of the vocal cords They conclude that they do not agree that clonic contraction of the intrinsic muscles of the larynx is possible at rates above 110 C/S, and in consequence they give their full support to the older tonic theory

Van den Berg[12] reports that Piquet and associates took some high-speed motion pictures of the vibrations of the vocal folds during total laryngectomy without an air stream through the glottis Certain observations were recorded pertinent to the cause of vibrations of the vocal cords Their conclusions play a role in the current discussion of the myo-elastic and neuro-chronaxic theories of voice production Van den Berg discusses these at length and believes that Piquet and associates' attempts to prevent a flow of air through the glottis were unsucessful

ABNORMALITIES

Alonso and Regules[13] describe a simple procedure for treatment of congenital and cicatricial webs in the anterior portion of the larynx in children and adults They briefly review the methods now being used for amelioration or correction of the existing conditions and then describe their method, which consists of removing the web through a laryngoscope and then placing a thin polyethylene semi-circular plate with nylon thread attached to the straight edge of the plate The two ends of the nylon thread are introduced through the mouth into the larynx and brought out through the thyrohyoid and cricothyroid membranes, by this means the polyethylene plate is placed in the anterior portion of the larynx This plate is held in place by tying the nylon thread over rubber tubing The authors used this procedure only one year and, therefore, they have not performed it on many patients The procedure has much merit and will be used by many laryngologists in the due course of time

Respiratory distress in dogs may result from a number of causes Leonard[14] reports five cases of eversion of the lateral ventricles of the larynx responsible for respiratory distress In three of these dogs the protruding ventricles were removed with a tonsil snare All recovered and were free from respiratory distress

DIAGNOSIS

In an article on the radiologic investigation of diseases of the ear, nose and throat, Samuel[15] states that radiologic examination of the larynx cannot be regarded as complete until the cervical esophagus has been filled with barium and its outlines demonstrated. He describes the technique used in obtaining these radiographs and extols the merits of films of good quality. Malignant growths of the larynx will obliterate normal workings. The lateral view is of great value in assessing subglottic extension of such neoplasms.

Pirozok and associates[16] propose a method for rapid histologic diagnosis of infectious avian laryngotracheitis. All agree that this infection is highly contagious and fatal. Gross pathologic examination usually yields inconclusive results and other diagnostic methods are time-consuming. The method of obtaining reliable histologic sections mounted on slides described by Pirozok and associates requires three hours. They use Carbowax$^{\mathrm{W}}$® as an embedding medium for sectioning tracheas in the differential diagnosis of laryngotracheitis.

Powers and co-workers[17] present the results of their anatomic study of the larynx in which they used a contrast medium to obtain radiographs. Experiments proved that use of Dionosil,® introduced slowly into the hypopharynx and larynx after topical anesthetization, offered the best results for interpretation of existing disease, and functional and anatomic abnormalities.

INSTRUMENTS

Martin[18] presents a new type of pharyngolaryngoscope with a wide proximal end tapering to the distal end and containing an electric bulb for proper illumination. The wide proximal end permits binocular vision of the base of the tongue and vocal cords. There are three sets of tapered tubes that fit on one handle. The instrument is best employed with use of a general anesthetic, as Martin says it is not always practical to use a topical anesthetic.

Pitman[19] presents a new instrument for examination of the larynx of patients having extremely sensitive throats and anatomic difficulties. This instrument, modeled after the pattern of a nasopharyngoscope, is called by Pitman a *naso-laryngoscope*. It is introduced through one nostril after proper cocainization of the nose, by means of proper lenses, prisms and light, it is possible to obtain a view of the larynx when the tip of the instrument is placed through the nostril into the nasopharynx, and the illumination is directed downward for visualization of the larynx.

The tubular portion of the Jackson laryngoscope has been modified by Heinberg,[20] so that it is no longer a closed tube as in Jackson's instrument. The modification consists of an opening about one-half inch wide along the tubular wall whereby such things as instruments and suction tubes may readily be passed in or out of the laryngoscope.

DISEASES

In an excellent article, Jones and Camps[21] report results of a study of 29 cases of acute epiglottitis. The clinical picture is well described. The diagnosis is suspected by recognition of upper respiratory obstruction and is confirmed by the appearance of the epiglottis. Early recognition and immediate hospitalization are most important. The treatment "par excellence" is tracheotomy. The specific infecting organism in their patients was the hemophilus influenza, Type B, which responded favorably to treatment with chlortetracycline, the drug of choice for this condition.

In a brief, uninformative article Chia[22] reports a case of a patient having two diseases simultaneously. He believed that the patient suffered from tuberculosis of the cervical glands and larynx, and from an osteogenic sarcoma of the tibia with a secondary deposit in the first rib.

Heinberg[23] states that many changes in the concept of laryngeal obstruction in children have occurred during the past three decades. The medical profession has realized that infections other than diphtheria can cause obstruction of the airway. Chemotherapy and the antibiotics have resulted in management of these cases by the family physician or pediatrician, however, when the laryngitis becomes obstructive, the laryngologist is called. Heinberg pleads for early teamwork to prevent anoxia and toxemia. He discusses the various causes of laryngeal obstructiton and outlines the therapy.

Contact ulcer has been attributed to excessive use of the voice and exposure to irritants Ulcers due to emotional strain have been reported Rubenstein[24] presents such a case of an ulcer that persisted for many years despite all methods of surgical and medical treatment Finally, the conditions producing the severe emotional strain were removed, and immediately the ulcer healed spontaneously

In a brief but interesting article Pearson[25] describes a case of rheumatoid arthritis of the larynx in a 61-year-old man who had had rheumatoid arthritis for more than 30 years Dyspnea, due to limited abduction on respiration, developed necessitating tracheotomy Death was due to respiratory infection and consolidation Histologic sections of the larynx showed changes in the crico-arytenoid joints characteristic of rheumatoid arthritis If laryngeal stridor occurs in a case of rheumatoid arthritis, the most likely cause is involvement of the crico-arytenoid joints by the pathologic process

In discussing rheumatoid arthritis of the crico-arytenoid joints, Copeman[26] states that it is strange that no article in the English language appears to have been written on this subject He describes the crico-arytenoid joints in minute detail The outstanding symptom besides partial or total ankylosis of the joint is local tenderness on pressure over the larynx between the thyroid and cricoid cartilages laterally or centrally Copeman reports in detail three cases of rheumatoid arthritis of the larynx He states that the differential diagnosis in these types of cases appears to lie only between rheumatoid arthritis involving the crico-arytenoid joints and paralysis of the recurrent laryngeal nerves

Baker and Bywaters[27] report a case of laryngeal stridor in rheumatoid arthritis due to involvement of the crico-arytenoid joint Classical rheumatoid arthritis had exisited for four years Dyspnea and dysphagia gradually developed The left cord became fixed in a position of adduction and the right cord showed progressive loss of abduction The patient responded favorably to Cortisone therapy The authors stated that in retrospect the laryngeal picture resembled that of bilateral abductor paralysis

Muñoz MacCormick[28] discusses the three distinct types of leprosy, namely, the lepromatous, the tuberculoid and the indeterminate from the standpoint of pathology and clinical manifestations Lesions involve the mucous membranes, especially the nose, in 90 per cent of cases In the lepromatous or malignant type, the larynx is involved in 28 per cent of cases The laryngeal pathology is discussed, and the differential diagnosis between this disease, tuberculosis and syphilis is discussed Lastly, the known treatment is briefly considered with emphasis on investigative studies of drugs like isonicotinic acid and corticotropin This is a most interesting and thorough discussion of this seldom seen disease in this country

Obregon[29] reminds us that pemphigus of the larynx, although rare, is of great importance to the laryngologist, because the larynx may be the first site of the disease He considers four main types foliaceus, erythematosus, vegetans and vulgaris He concludes that pemphigus vulgaris is the type most frequently found in the larynx and reports two such cases Use of the Tzanck or Cantharides tests confirmed the diagnosis Corticosteroid therapy gave excellent results in both cases

Coleman[30] calls attention to the fact that apparently benign dysphagia associated with chronic hypochromic anemia in what is commonly known as the Plummer-Vinson syndrome must be regarded as a precancerous state, as it may progress to post-cricoid carcinoma The syndrome is almost exclusively confined to women Coleman reports the unusual case of a man in whom hypochromic anemia developed after partial gastrectomy The syndrome progressed to post-cricoid carcinoma, which is fairly common in women but hitherto unrecorded in a man

In a most interesting article Silcox[31] describes the powerful effect of corticosteroids in otolaryngological conditions Its anti-inflammatory action is fully discussed as well as its action on connective tissue permeability Use of corticosteroids for brief periods is reported as beneficial in acute edema of the larynx, contact ulcers and laryngeal polyps Silcox stresses the fact that corticosteroid therapy alone is never curative and always potentially dangerous

DIVERTICULA

According to Walls,[32] the diagnosis of laryngocele presents no difficulty provided the condition is kept in mind, since the lesion is rare The various types of laryngocele are described The symptoms will depend upon the extent of development and the location of the dilatation Usually the tumor enlarges when the intraglottic air pressure is increased Walls reports a case of bilateral laryngoceles of considerable size which were surgically removed with excellent results In his bibliography Walls fails to mention Felix LeBorgne of Montevideo, who presents many roentgenograms of laryngoceles in his excellent book on radiography of the larynx

Kodicek[33] reports a case of bilateral external laryngoceles in a man 77 years of age who had been blown up by a shell during the first World War His voice was extremely hoarse, and the large bilateral swelling in his neck was a source of much interest to his friends Palpation of the neck during quiet respiration revealed no abnormality When he was asked to phonate, an air-filled cyst appeared on each side of his neck in front of the sternocleido-mastoid muscle and extended from just below the angle of the lower jaw to about the level of the cricoid Kodicek describes three types of laryngocele and presents a diagram outlining these cysts He points out that these cysts of the laryngeal ventricle and saccule show great similarity to the ventricular air sacs present in some monkeys and apes

Price and associates[34] review briefly the early history of laryngoceles and the anatomy of this region The etiology, diagnosis and complications are discussed briefly, and the surgical technique for extirpation of a laryngocele is described in detail Two cases of successful operation are reported

PARALYSIS

Sometimes in hemiparalysis of the vocal cord an extreme lateral position of the cord is assumed Goodyear and Hogg[35] transplanted a section of cartilage from the superior border of the thyroid cartilage to correct this condition. This was inserted the length of the cord after the cord had been elevated following thyrotomy. When the patient was seen 21 days later, her voice was satisfactory and she was to return to work as a telephone operator the next day.

Reaves[36] states that the main factor in the differential diagnosis of bilateral abductor paralysis of the larynx and bilateral crico-arytenoid ankylosis is the fact that mirror laryngoscopy shows typical bowing of the anterior two-thirds of the cords on inspiration. The basic facts to be kept in mind are that in one there is permanent loss of muscle function, and in the other the laryngeal muscles are temporarily impaired in their action owing to immobile arytenoids. Reaves advocates bilateral arytenoidectomy for correction of bilateral crico-arytenoid ankylosis.

Neurologic complications have been described after injections of such antisera as tetanus, gas gangrene, diphtheria, pneumococcus, streptococcus, typhoid and rabies. The site of injection appears to be unimportant. Radiculitis affecting the fifth and sixth cervical roots is the most common anatomic site of neurologic complications of prophylactic inoculations. Bauer and Ellis[37] report a most interesting case in which a 31-year-old man received antitetanus serum into the right arm because of a cut on a finger. One week later development of neurologic symptoms necessitated hospitalization. Later paralysis of the right vocal cord developed, but four months later it spontaneously subsided. Bauer and Ellis concluded that the paralysis of the recurrent laryngeal nerve was undoubtedly a part of a generalized disease, and they express the hope that for prevention of tetanus, active immunization in the form of toxoid be used in preference to passive immunization by antitoxin, as it is less likely to cause neurologic complications.

In a most excellent, interesting article Arnold[38] presents the current concept of laryngeal paralysis. He prefaces his paper with the statement that whereas the advent of new drugs or bacteriologic advances have radically altered most aspects of medical practice, the problems of normal and diseased laryngeal innervation remain the same Arnold attempts to define the major problems of laryngeal paralysis by analyzing the representative bibliography from the following viewpoints value of animal experiments, chronologic changes in the concepts of laryngeal disease, discussion of central pathways and the peripheral course of the laryngeal nerves, *variability of terminal ramification of the recurrent* nerves and the present interpretation of the position of the paralyzed cords Semon's law is discussed at great length, and numerous opinions are quoted The conclusion reached is that Semon's rule of the greater vulnerability of the abductor fibers represents a clinical observation that signifies either an incipient sign of a progressive lesion or a terminal sign of subsiding paralysis

Melampri[39] presents a brief review of the occurrence of laryngoplegias in pseudobulbar paralysis, labioglossopharyngeal paralysis, multiple sclerosis, syringomyelia and tabes dorsalis observed between 1942 and 1956 On the basis of his personal findings and those of the reviewed literature the frequency of laryngoparalysis in the diseases mentioned appears unvaried with the exception of tabes dorsalis, which has shown a progressive reduction in incidence This may be the result of more efficient social prophylaxis, particularly introduction of the recently discovered treatments

Thornell[40] states that paralysis of the *vocal cords may* result from a variety of causes The most frequent cause of bilateral paralysis of the vocal cord is injury to the recurrent laryngeal nerves during thyroidectomy Bilateral paralysis in which the vocal cords are fixed in the median line is an extremely critical condition Emergency tracheotomy is usually necessary because the airway is inadequate In order to create an adequate airway Thornell devised intralaryngeal arytenoidectomy, which is performed with the aid of the Lynch suspension laryngoscope This ingenious procedure provides satisfactory results in the majority of cases We *thoroughly concur in* Thornell's warning against laceration of the mucous membrane on the medial aspect of the cartilage, as this will nullify the attempt to increase the glottic space

The findings of unilateral recurrent laryngeal nerve paralysis in an infant 11 months old aroused considerable interest, and because of its rarity, Ross and Chambers[41] report the case Two weeks before admission to the hospital the child cried with a hoarse voice Laryngoscopic examination revealed abduction paralysis of the right vocal cord No cause for the paralysis could be found at the time Two months later the condition became worse and bilateral papilledema developed At necropsy a tumor of the right side of the pons and medulla was found

Asherson[42] informs us that achalasia of the cricopharyngeus invariably accompanies bilateral recurrent laryngeal nerve paralysis In six of eight cases reported, some obstruction to swallowing of fluids could be demonstrated clinically In this form of achalasia there is little or no obstruction in swallowing solids Asherson reports a case of achalasia of the cricopharyngeus developing after bilateral abductor paralysis caused by bronchogenic carcinoma

Occurrence of postoperative laryngeal paralysis does not necessarily imply that the recurrent laryngeal nerve has been severed Ross and Sukis[43] carefully explain that there are many other causes for laryngeal paralysis and dysfunction, which are discussed in this excellent article The anatomy and variations of the recurrent nerve and its branches are well described The superior laryngeal nerve and its two branches are prone to injury in certain surgical procedures The importance of preoperative examination of candidates for thyroidectomy is stressed and repeated postoperative examinations are necessary because of the amazing changes that occasionally occur in the larynx When paralysis is unilateral, the patient can be encouraged by assurance that one-half of these paralyses are transient

STENOSIS

Tschiassny[44] discusses the various experiments producing laryngeal stenosis by bilateral division of the recurrent nerve with relief by inactivation of the cricothyroid muscle The experiments were conducted on animals and later on man with identical results These results brought forth a vigorous discussion relative to the validity *of Semon's law, and much* consideration is given to this problem Factors responsible for the cadaveric position of the vocal cords are considered, and results obtained by neurotomy of the superior and inferior laryngeal nerves are reported Superior laryngeal neurectomy resulted in the vocal cord's assuming the cadaveric position with a good airway In an extensive and interesting discussion Tschiassny presents factors responsible for failure and success of crico-arytenoid elimination and dwells at length on the mechanism responsible for opening the glottis as well as factors interfering with this opening He concludes that cricothyroid *elimination* cannot replace *modern and* the more complex methods of arytenoidectomy, lateropexy, or both, but that this technique may be used advantageously when restricted to its own territory

Milne[45] reports that introduction of an intubation tube *into a patient's larynx for induction of anesthesia* produced sufficient irritation in the subglottic region at the level of the cricoid cartilage eventually to cause dyspnea It is supposed that in this patient there occurred gradual development of stenosis at the level of the cricoid cartilage as a result of chronic but not pronounced inflammation, and passage of the tube produced acute exacerbation of the condition with narrowing of the lumen There is nothing in this report, however, to substantiate this supposition The stenosis was corrected by laryngofissure and Thiersch graft

SURGERY

In a unique article Bofenkampf[46] describes a relatively simple corrective operation for relief of aphagia after poliomyelitis The anatomy and physiology of the cricopharyngeus muscle are described Two cases of aphagia of three years' duration after poliomyelitis treated by denervation of the cricopharyngeus muscle are reported Through an incision *on the side of the neck the thyroid and cricoid* cartilages are exposed and rotated laterally and outward The cricopharyngeus *muscle is identified, and a small section* is removed from its posterior aspect In both patients thus treated normal swallowing occurred within 24 to 36 hours, and normal swallowing has persisted

In a most interesting and informative article on laryngeal and tracheal emergencies in the newborn, Miller[47] indicates the procedure for proper diagnosis Obstruction of the airway in the newborn or extremely young infant is a real emergency requiring accurate diagnosis to institute life-saving measures This at times can be difficult in these tiny patients

Miller enumerates the various problems that may contribute to obstruction of the airway, and concludes that many conditions other than atelectasis of the newborn and laryngeal obstruction must be considered in the very small infant presenting respiratory distress that requires emergency treatment All laryngologists should review accurate and concise articles such as this one in order to refresh partially forgotten facts

Lewis, Smitman and Loewy[48] describe and illustrate each stage of the reconstruction methods employed by them after laryngopharyngectomy Reconstruction of the hypopharyngeal-esophageal tube is undertaken as soon as the original wound has completely healed The various problems arising when doing this type of work are thoroughly discussed The illustrations of the methods of reconstruction make a difficult problem seem easy

In addition to cordal carcinoma DeBord[49] reports use of the laryngofissure approach for removal of foreign bodies, cysts and benign tumors, and for arytenoidectomy in patients with bilateral abductor paralysis For such conditions this approach provides better vision and enables manipulation and careful approximation of the mucosa postoperatively

Howie[50] reminds us that the operation of laryngofissure has many uses It is the only way to remove impacted foreign bodies in the larynx that have resisted removal by direct laryngoscopy Injuries and trauma to the larynx may require laryngofissure to readjust displaced fragments of cartilage or stenosis occurring from various causes enumerated in this article The main object of the laryngofissure operation is management of early cordal cancer, and the ideal type of lesion is a tumor of low gradation in which both extremities of a mobile cord are free Howie quotes statistics of British and American laryngologists on percentage of cures by laryngofissure and mentions use of radiation and teleradium in a provocative vein The conclusion reached is that laryngofissure used in proper cases gives excellent results This paper was freely discussed by Sir Victor Negus, Capps, Macbeth and many others who generally agreed with Howie and added nothing new to the original article

Clinical studies dealing with the psychologic reaction of the patient to laryngectomy, and those studies that evaluate the progress made by laryngectomized patients in programs for speech rehabilitation, should include all patients referred to a given program In this excellent article on evaluation of rehabilitation programs Lueders[51] advocates that a team comprised of the laryngologist, the speech therapist and the psychologist would appear to be best fitted for the task of evaluating the factors inherent in the non-cooperating group of patients Broadly, he states that the purpose of this team would be to determine by physical and psychologic examinations and by clinical experience whether esophageal voice training or a speech prosthesis (electro-larynx) is indicated to achieve maximum rehabilitation

In a discussion of the pseudoglottis in laryngectomized patients Micheli-Pellegrini[52] rejects the possible existence of pharyngeal elements capable of vibrating like vocal cords He does not believe that any esophageal element, and in particular the cricopharyngeus, is able to simulate a vibrating glottis Views of the various contributers on the subject of the so-called pseudoglottis in laryngectomized patients are discussed, mostly to disagree Michelli-Pellegrini believes that air flowing through a narrow section would produce sound, and that the most probable site for such a narrowing space would be between the base of the tongue and the posterior pharyngeal wall He states that the esophageal mouth constituted by the cricopharyngeus seems to represent those structures at which level fundamental sound is produced in the laryngectomized patient From reading this article it is evident that no unanimity of thought exists concerning the production of sound in a laryngectomized patient

Simon[53] is of the opinion that any operation on the thyroid gland, no matter how trivial, endangers the recurrent laryngeal nerve He believes that the incidence of nerve injury in thyroid surgery is much higher than present statistics indicate Non-functioning recurrent nerves are a terrific handicap and frequently blight the patient's life Simon maps out a triangle for protection of the recurrent nerve The triangle is bounded laterally by the common carotid artery, superiorly by the inferior thyroid artery and medially by the body of the recurrent nerve on the lateral border of the trachea Location and visualization of the nerve in this triangle practically assure that it will not be injured provided adequate care and gentle technique are observed

Mettler[54] reports a case of a mediastinal abscess that apparently lay dormant for seven months after laryngectomy It was diagnosed by roentgenography with use of barium, opened and drained

VOICE THERAPY

It has been noted that patients with simple conduction deafness tend to speak softly Cantor[55] suggests that in advising a patient to rest his voice a conduction deafness can be produced artificially by means of ear stoppers or ear muffs

The first part of Briess' article[56] deals with the history of voice therapy dating from the discovery of the laryngoscope by Garcia in 1854 This is followed by a discussion of the theory of voice production and the interplay of the laryngeal muscles in accomplishing this

Next is brought out the classification of the voice therapist and the order of testing depending upon the condition of the patient, whether there is a lesion on the cords, and the pathologic type of lesion The methods are then considered, and the techniques of carrying out these tests are explained This is the first part of a subsequent series of articles in which the means of correcting muscle pairs that are functioning out of balance will be described

Gartland[57] reports a case of injury to the thyroid cartilage without fracture producing a hematoma of the false cord and swelling of the arytenoid with fixation of the cord They used interrupted galvanic current under direct laryngoscopy to determine whether paralysis of the cord was due to nerve injury or to dislocation of the arytenoid The voice recovered for every day needs, but the cord remained immobile

Livesey[58] reports the case of a 20-year-old soldier who fell and struck his neck on a tent-peg Aphonia, coughing, hemoptysis and some pain developed immediately followed by dyspnea later The next day emergency tracheotomy was necessary Subsequent examination of the larynx showed a large hematoma on the left side Livesey warns that any heavy blow on the larynx may result in severe dyspnea and such accidents should never be considered too lightly

FOREIGN BODY

Zoller and Bowie[59] state that several cases have been reported in the literature in which calcifications of the neck were confused with foreign bodies of the food passages Calcification of the neck occurred in three successive cases of suspected foreign body of the esophagus in which the patient gave a history of swallowing a chicken bone and on esophagoscopy no foreign body was found These patients presented the problem of calcification of normal laryngeal cartilages These cases prompted Zoller and Bowie to review the literature and launch an investigation of this problem Numerous radiographs appear in the article showing normal calcifications of isolated portions of the laryngeal cartilages giving the impression of a foreign body It is acknowledged, however, that 98 per cent of foreign bodies of the esophagus are below the lower border of the cricoid cartilage

Feldman and associates[60] report a case of a piece of wooden tongue depressor breaking and being aspirated by the patient during a convulsive seizure A plea is made for care in the use of wooden tongue depressors under similar circumstances, and the danger is emphasized

BENIGN TUMORS

Epstein and Winston[61] express the opinion that intubation granuloma is a rare complication of endotracheal anesthesia There is no doubt that this condition is far more common than the 55 published cases would suggest Epstein and Winston state that intubation granulomas are invariably found on the vocal processes of the arytenoids We agree that the vocal process is by far the most frequent site of occurrence, but in our series of 25 unreported cases, we have had two patients in whom the granuloma occurred in the middle third of the vocal cords The histologic picture of these granulomas is simply that of nonspecific granulation tissue Various theories have been postulated in an attempt to explain their cause and site Evidence is offered to incriminate the role of static pressure rather than direct trauma as the most important etiologic factor

In an editorial[62] further emphasis is placed on the fact that greater care should be exercised in the introduction of the endotracheal tube at the time of induction of anesthesia in order to avoid the occurrence of granulomas

Figi and Berman[63] state that although primary amyloid deposits occur in many parts of the body, they are found most frequently in the laryngotracheal region Nine cases of amyloid tumors occurring in the larynx and trachea were seen during a period of six years, one of which is reported in detail Hoarseness was the chief complaint of all patients, and the treatment found most effective was surgical removal

Szpunar[64] correctly states that papillomatosis of the larynx in children represents a different morbid process from papilloma of the larynx of adults Whereas hyperkeratotic papilloma in the adult is considered a precancerous lesion, malignant degeneration of papillomatosis occurs rarely in children It is now thought that laryngeal papillomatosis in children does not undergo malignant degeneration unless irradiated For this reason, there is belief that irradiation and radical surgical excision should be banned in the treatment of laryngeal papilloma in children. Szpunar comments on the varied unsuccessful treatments used for papilloma of the larynx and then describes the treatment he used in 80 cases of multiple papillomatosis from 1946 to 1956 with good results. This consisted of injection of 0.1 to 0.5 ml. of stilbesterol into the larynx. Only one side of the larynx was injected at one time, as occasionally moderate swelling develops.

Studies in tissue growth of laryngeal papilloma were conducted by West and co-workers[65] using the suspended cell methods patterned after techniques suggested by Hanks. Observations suggested growths occurred more rapidly from laryngeal papilloma obtained from the larynx of both children and adults, than any other adult tissue cultured, either benign or malignant.

Woodman[66] presents a follow-up report of a case of a woman, aged 35 years, with multiple obstructive papillomas treated by a surgical technique in which a laryngofissure approach was used with submucosal dissection of the growth followed by insertion of an acrylic mold. The patient has remained free of recurrence for three years.

Capps[67] made a survey of the treatment of papilloma of the larynx by circulating a questionnaire to a number of colleagues in charge of clinics, he received 80 replies. He rightfully concluded that no accepted therapy will control these growths. The various treatments advocated are listed. The probable cause of stenosis in these cases is injury to the vocal cords and violation of the anterior commissure. In the treatment of such stenosis Capps advocates thyrotomy with excision of scar tissue and Thiersch grafts.

Huizinga[68] brands laryngeal papilloma as a mysterious tumor and from the present outlook fears that it will remain mysterious. Microscopically, there is no difference between papilloma in the child and in the adult, or between single papilloma and multiple papillomas. Huizinga admits that little is known about the etiology of multiple papillomas. He calls attention to the increase in incidence of multiple papillomas in Finland and the Netherlands after World War II, which he attributes to bad hygienic and social conditions We have been of the opinion for years that multiple papillomas occur predominantly in underprivileged children

Ono and associates[69] present a masterly discussion of the etiology of multiple papillomas and describe experiments unsuccessfully conducted for determination of the etiology Papilloma is the most common benign tumor of the larynx with the exception of the polyp, which is an inflammatory hyperplastic lesion The striking features of this tumor are its frequent occurrence in children, its resistance to treatment, its tendency to transplant itself, its tendency to recur and its spontaneous regression and disappearance after its existence for a number of years Among the possible etiologic factors discussed are hormones, chronic irritation and virus infections The thought is expressed that clinical and experimental observations point to the fact that virus is most likely a major causative agent This is an excellent presentation, which should be read in its entirety by those interested in this subject

Vettorato[70] reports a survey of 38 cases of papilloma of the larynx in children and adults and describes his therapy

Bjork and Hakosalo[71] conducted a study on the mitotic activity in benign and malignant papillomas of the larynx in adults, because it offered additional possibilities for evaluation of intra-epithelial anaplasia Pathologic mitosis is extremely rare in benign papillomas but fairly common in malignant papillomas The frequency of mitosis, and of pathologic mitosis in particular, is an important criterion in consideration of the possibility that papillomatous formations in the larynx are malignant.

In an interesting, informative article Bjork and Terr[72] report results of the comparative clinical and histologic study of benign and malignant papillomas of the larynx in adults Many authorities agree that the diagnosis of malignant tumor is often difficult to make in the case of papillomas Ullman is quoted as stating that single papillomas in adults show a tendency to malignant degeneration, and Altman is quoted as saying that intra-epithelial anaplastic changes are conclusive evidence of malignant growth in non-papillomatous laryngeal tumors, whereas the same signs in papillary tumors are less significant, however, Bjork and Teir consider intra-epithelial anaplastic changes to be of utmost significance in determining malignant degeneration Critical distinction is necessary in evaluating epithelial changes since benign papillomas can show some degree of atypia

Ciacovaner and Chodosh[73] report two most interesting cases One presented unusual symptoms and the other unusual therapeutic requirements The first patient suddenly noted a "fleshy mass" in his mouth On mirror examination of the larynx a large pedunculated mass was noted in the left pyriform fossa, the pedicle arose from the inferior portion of the left posterior pillar The possibility of glottic obstruction was appreciated, and surgical removal was accomplished without difficulty The second patient had a ventricular polyp which had to be removed by a laryngofissure approach Other polyps were encountered on the cords Seldom is it necessary to resort to such a procedure to remove polyps from the larynx, but large ventricular polyps present problems which at times, such as in this case, require a laryngofissure approach

Plasmocytoma is an uncommon tumor of the soft tissues of the upper respiratory tract, and as an intrinsic tumor of the larynx it is extremely rare Clark[74] reports such a case that caused recurrent hoarseness, dyspnea and dysphagia for two or three years On indirect laryngoscopy a large, soft polyp was seen between the vocal cords and appeared to originate from the right ventricle After removal, the pathologic diagnosis was plasmocytoma

Epiglottic cysts complicating anesthesia are rather uncommon Norris[75] reports two such cases which presented problems to the anesthesiologist Cysts of the epiglottis are not considered rare by the laryngologist, and frequently when found, they are symptomless Only when they assume large proportions, do they present problems Norris discusses the origin and classification of cysts of the epiglottis and the method of handling such cases when administering an anesthetic The difficulties and dangers resulting from unsuspected epiglottic cysts encountered during general anesthetization are well discussed

Asherson[26] states that a cyst of the epiglottis is usually considered to be a benign lesion, but this classification belies its deadly nature and is misleading if the cyst is large The most lethal of such cysts, despite their relatively small size and rarity, is the congenital juxta-laryngeal cyst that is a common cause of laryngeal obstruction in the neonate, 15 out of 20 resulting in death from asphyxia within a few weeks of life Even in the adult, large cysts of the epiglottis become dangerous as they increase in size and a pedunculated cyst may become impacted in the glottis with resultant asphyxia and death Asherson describes the various types of cysts and attempts an interesting classification of them He advises peroral removal of all cysts occurring in the epiglottis and upper portion of the larynx with the aid of the Davis tonsil mouth gag and removal of the plunging intra-laryngeal cyst by the external approach It is strange to the reviewers that Asherson does not mention utilization of suspension laryngoscopy for removal of laryngeal cysts, which to us is the ideal method

Epstein and co-authors[27] agree that in spite of much writing on vocal cord polyps, considerable confusion still exists in the literature as to nomenclature and histologic interpretation Their objective in this presentation was to analyze and assess the clinicopathologic significance of vocal cord polyps They analyzed 283 cases of vocal cord polyps histologically and clinically and discuss the pitfalls of nomenclature Polyps and their clinical variants are not neoplasms, consequently, use of such terms as fibroma, angioma or myxoma is not correct True benign neoplasms of the vocal cord, with the exception of papillomas, are excessively rare This is a most excellent article and should be studied by the laryngopathologist

In an excellent, thorough article on benign tumors of the larynx, Capps[28] excluded from discussion nodes, polyps, cysts and some fibromas, which are probably the result of trauma or inflammation He states that compared with malignant growths of the larynx, benign tumors are rare Papillomas are outstanding and account for nearly all growths occurring in infancy The therapy of multiple papillomas is discussed generally with the expected conclusion that there is no specific remedy available This latter fact is brought out forcibly by quoting numerous articles on multiple papillomas Capps reports one case of a fibroma simulating carcinoma Two cases of angiomas and one lymphoma are included Five chondromas were seen, and the literature of recorded cases is reviewed

In a discussion of benign tumors of the larynx Salkeld[79] reports a case of a non-specific granuloma of the larynx in a 68-year-old man, which was removed by laryngofissure with recurrence in four months Radiation partially controlled the growth The lesion was studied by several pathologists, who concurred that it was an inflammatory granulomatous tumor with abundant plasma cells At the time of their report the patient was receiving extensive corticosteroid therapy

Following the shock of an air raid 13 years before, a patient became hoarse, and six months later when examined, paralysis of the right vocal cord was found In 1953 Salmon[80] investigated the larynx because of recurring hoarseness and found a large, rounded mass expanding the right aryepiglottic fold Roentgenograms were characteristic of an ossifying chondroma of the right arytenoid Utilizing a curved lateral incision and making use of the Woodman arytenoidectomy approach he removed the tumor, and the diagnosis was confirmed

Stewart[81] discusses the histopathology found in a series of 104 cases of benign tumors of the larynx Polypoid-like growths occur in the larynx with relative frequency, and these inflammatory polyps are regarded as formations of mesenchymal origin as the forerunners of fibromas and angiomas Stewart considers the fibroma as the most common of the differentiated benign tumors occurring in the larynx These, together with angiomas, are described thoroughly from a histopathologic aspect and microphotographs are presented to substantiate the diagnosis

MALIGNANT TUMORS

Pirkey[52] reports a case of a metastatic laryngeal lesion of a proved case of multiple myelomatosis This is extremely rare, particularly because metastasis to the larynx scarcely ever occurs Of interest in this case was the rapid favorable response of the lesions to administration of urethane Although the patient died, as long as urethane could be given improvement was steady, however, use of the drug had to be discontinued because it caused severe leukopenia

In a lengthy article Lane[53] reports ten cases of polypoid or fungating oral, faucial and laryngeal lesions The features they had in common were the presence of an intramucosal or invasive squamous cell carcinoma associated with an anaplastic stroma of sarcomatous appearance Only two of the ten patients had a history of radiation to the region in question Pathologic study of these cases suggested that only the carcinomatous portion had truly malignant neoplastic properties Lane suggests that the sarcomatous component of these growths is probably not a malignant neoplastic tissue, and for this reason proposes the tentative designation of "pseudosarcoma"

Kuhn and associates[54] present a detailed, extensive statistical report on 602 cases of carcinoma of the larynx They classified their cases not only as to age, sex and duration of symptoms but also as to site and grade They concluded that the findings of their study "indicate that among various items of information available at the time of treatment, the site of the tumor, the histologic grade of the tumor and the microscopic infiltrative nature of the tumor, each significantly affects the likelihood of occurrence of cervical metastases from patients with squamous cell carcinoma of the larynx" They considered their findings determinants of the indications for radical procedures designed to remove cervical areas of metastatic spread in this disease This is an excellent reference article

Quinn and McCabe[85] found only eight cases of laryngeal metastases from distant organs in a review of the literature from 1916 to 1951 To this group they added two cases of carcinoma of the prostate gland that were metastatic to the larynx These cases are well described, and the route by which neoplastic emboli reached the larynx is discussed

In a most interesting and valuable contribution on pharyngolaryngectomy with primary "sleeve graft" reconstruction, Shaw and Omerod[86] describe their technique for successful handling of these difficult cases Much stress is placed on the importance of using the proper type of self-retaining Latex stents originally devised by Sir Victor Negus It is agreed that total pharyngolaryngectomy with primary closure by skin tube must be used when resection of the primary tumor in the hypopharynx or cervical esophagus necessitates excision of more than 70 per cent of the mucosal circumference The incision and resection are matters of skill and surgical judgment A rectangular split skin graft of sufficient size (4x6 inches) to create a "sleeve" type tube for the upper gullet is used This graft is applied to the operative defect, raw surface outward, and is sutured to the lower edge of the posterior pharyngeal wall and the upper edge of the posterior esophageal wall The Latex stent is placed in position, and the graft is carefully sutured around the hourglass stent Complications and postoperative treatment are discussed Those interested in this type of surgical reconstruction should read the entire article, which is much too long to cover adequately in such a review as this

Marchetta and co-authors[87] present the end-results of a study of 158 documented cases of carcinoma of the larynx seen from 1935 to 1953 They concluded that the smoking history in this series was of little significance They divided their cases into three categories the first category included 56 cases in which the lesion was confined to the vocal cords without evidence of fixation Half of these were treated by excision and half by radiation Twenty-four months after treatment 75 per cent of the surgical group were free of disease, whereas only 50 per cent of those treated with radiation were without recurrence The second group consisted of 60 patients with lesions limited to the cords with fixation indicating deeper infiltration of the structures of the larynx. Eighty-three per cent of the patients treated surgically showed no evidence of recurrence at the end of 24 months, whereas only 22 per cent of those treated by irradiation were free of disease at the end of this time. In the third category were 42 patients with lesions that involved the ventricular band in addition to the true cords. All seven treated surgically were alive at the end of 24 months, but only 11 per cent of the remaining 33 who received irradiation were alive at the end of this time. Surgical treatment consisted of laryngofissure, laryngectomy or laryngectomy with radical neck dissection. Salvage efforts were instituted whenever possible. This presentation is of great interest, and only the outstanding statistics have been presented because of the length of the paper.

Jackson and associates[58] report the results of a survey of 25 years' experience with treatment of 1,066 patients with carcinoma of the larynx by operation and irradiation. Treatment consisted of partial laryngectomy in 384 patients, total laryngectomy in 374 patients, laryngectomy with radical neck dissection in 48 patients and irradiation in 260 patients. The five-year survival rate, as would be expected, was highest in those having partial laryngectomy (87 per cent) and lowest in those treated by irradiation (42 per cent). Metastasis and recurrence are discussed, and their management is outlined.

In a study of 170 case histories of patients suffering from cancer of the larynx Fior[59] was able to show that 32 relatives had suffered from some form of malignant lesion. These findings are discussed, and the importance of extrinsic factors which, by acting on the larynx, might enhance the hereditary cancer potential already existing in these subjects, is pointed out.

Foxwell[60] reports two interesting cases of carcinoma of the larynx in which he questions whether redevelopment of carcinoma 15 and 17 years later was a recurrent or a secondary primary lesion. The first patient was a laryngofissure in 1935 when the right vocal cord, which was fixed and had "an irregular white mass," was removed. Fifteen years later a growth developed on the left vocal cord and required laryngectomy. In the second case laryngectomy was performed in 1938, and a mass developed above the tracheal stoma in 1955. We concur that the first case was a second primary carcinoma, but we cannot understand the rationale of laryngofissure in the face of fixation of the cord. The choice was undoubtedly the proper one, for there was no recurrence on the side of operation. In the second case recurrence is a possibility.

There is universal agreement with Morfit and associates[91] that cancers arising in the laryngopharynx, extrinsic larynx, and upper cervical esophagus present difficult therapeutic problems. The main method of treatment in the past has been irradiation. Cancer therapists are now turning with greater frequency to surgical excision to improve results. Eleven patients were subjected to laryngopharyngectomy partial esophagectomy and neck dissection. The lesions were so extensive that after removal, primary closure was impossible and continuity was established with polyethylene. The method of doing this is well described. Morfit and associates conclude that when the growth can be extirpated by combined neck dissection, laryngectomy, partial pharyngectomy and primary closure obtained, the end-results indicate this is worthwhile. If the growth is so extensive that auxiliary measures must be employed, little or no increase in the salvage rate can be expected.

Snitman and Loewy[92] state that adequate surgical treatment of carcinoma of the larynx implies resection of the primary tumor and its path of direct and lymphatic spread with a true margin of safety. Laryngofissure techniques are satisfactory for restricted lesions, however, it is important to evaluate the indications carefully and adhere to them. For more extensive lesions of the vocal cord with relatively poor lymphatic-spread potentials, total laryngectomy is proper treatment. The various types of lesions occurring in the larynx and adjacent tissue are discussed. In all of these cases Snitman and Lowey comment on the type of operation considered adequate for the particular lesion. Laryngectomy in continuity with neck dissection is in frequent demand for certain types of lesions When indicated, they believe that laryngectomy should be of the widefield type, including the bloc from the hyoid to the trachea This is a most interesting and informative article replete with sound judgment and good advice

Thompson[93] reports that carcinoma of the larynx represents 4 per cent of all malignant lesions and more than 16 per cent of all laryngeal tumors It is most prominent in the fifth to seventh decades of life but has been reported in children as young as 11 years The ratio of men to women is ten to one and of Negro to whites per population is 1 to 1 5 per cent Thompson presents a series of cases illustrating the types of laryngeal carcinoma and methods of treatment

In an excellent article on laryngeal cancer Snitman and Loewy[94] deplore the inadequate type of operation in which lymphatic spread has not been covered They believe that the treatment of advanced carcinoma of the larynx is fundamentally surgical Relatively few patients with advanced carcinoma of the larynx demonstrate absolute contraindications to surgical management when they first seek medical aid In the past patients with advanced tumors were referred for radiation therapy, not in the hope of cure but for presumed palliation Many patients can now expect useful extension of their life span if given the benefit of adequate surgical excision This article is well worth reading

In an excellent article Holinger and associates[95] discuss the symptoms of laryngeal cancer with particular emphasis on persistent hoarseness As the condition develops, other symptoms appear Most of these tumors are squamous cell carcinomas Their location is described, and the symptoms resulting are given The diagnosis is made by indirect and direct laryngoscopy and biopsy Treatment consists of laryngofissure, and laryngectomy alone or with radical neck dissection The preoperative care and especially the postoperative nursing care are described in detail This is an excellent article for floor nurses as well as private duty nurses caring for this type of patient

Ormerod[96] defines pharyngolaryngectomy as total excision growth developed on the left vocal cord and required laryngectomy In the second case laryngectomy was performed in 1938, and a mass developed above the tracheal stoma in 1955 We concur that the first case was a second primary carcinoma, but we cannot understand the rationale of laryngofissure in the face of fixation of the cord The choice was undoubtedly the proper one, for there was no recurrence on the side of operation In the second case recurrence is a possibility

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Fluoroscopy confirmed the fact that air did not enter the esophagus because of inability to relax the sphincter of the esophagus Educational methods soon brought results A large esophageal bougie was used daily to dilate and relax the cricopharyngeal sphincter The patient gradually succeeded in swallowing air and pressing it out of the esophagus, and within two months a satisfactory conversational voice had developed

In an interesting article Haas[100] presents his recent work, although limited, on the betatron treatment of carcinoma of the larynx This presentation offers food for thought and again brings up the old argument of radiation vs excision as curative therapy for carcinoma of the larynx The advantages of the betratron are greater penetration, lesser surface dose, insignificant side scattering and, therefore, less osseous absorption and risk of necrosis of bone and bone marrow depression This type of treatment employs less radiation and causes less discomfort to the patient both during and after radiation Only ten cases of carcinoma of the larynx are reported, three of the ten patients are dead, and at the time of the report only one has been living for more than five years

McReynolds[101] considers carcinoma of the larynx an interesting and challenging problem in which the ideal treatment is yet to be found He reviews 244 cases of laryngeal cancer seen at the University of Texas Medical Branch during the past 15 years He reviews the modes of therapy employed and discusses at length and accurately the significance, potentialities, method of treatment and prognosis of leukoplakia Although his percentage of reported cures seems slightly low, his advice and surgical management are sound

Struben[102] comments on the difficulty of classifying laryngeal carcinoma, as evidenced by the divergent classifications proposed by various laryngologists He presents a classification proposed by the joint staffs of the Radiotherapeutic Institute of Rotterdam and the Netherlands Cancer Institute of Amsterdam, which is much the same as that suggested by the International *Committee for stage-grouping in cancer in* 1953 A universally accepted classification would make it of the larynx with at least half of the pharyngeal tube He adequately describes the pathology and surgical procedure, but dwells more on the methods of repair after this formidable operation His method of suturing and repairing the pharyngeal defect is well presented He points out that the condition of these patients is much improved by this drastic surgical procedure, the discomfort occasioned by the presence of a large septic malignant lesion in the pyriform fossa where air and food passages cross, being exchanged for the well being and comfort of a healed and clean alimentary tract

The immediate effects of too much Roentgen-ray irradiation on the skin, subcutaneous tissue and cartilage are well known Reports of late damage to the deep tissues of the pharynx, larynx and upper esophagus are not common Henry[97] reports two cases of damage from prolonged irradiation for noncancerous lesions ten to 15 years before Severe dyspnea and dysphagia developed in one patient, and in the other carcinoma of the larynx developed Henry voices the opinion that when cancer occurs several years after prolonged roentgenotherapy for a noncancerous lesion at the site of irradiation, it may be termed an irradiation cancer

The prognosis of carcinoma of the epiglottis is much worse than that of the vocal cords There seems to be a wide variation in the surgical management of this condition McCall and associates[98] believe that the solution lies in use of more radical excision They advocate total laryngectomy, including the epiglottis and radical neck dissection (unilateral if the growth is localized to one side, but bilateral in two stages if the growth is in the midline) To substantiate this procedure the lymphatic supply of the epiglottis and larynx is illustrated Statistics during a period of ten years show a higher incidence of recurrence in patients having less radical operations Helpful advice in performing bilateral radical neck dissections is offered

In an interesting and unusual paper Damsté[99] describes improvement of the voice of a patient after total laryngectomy by changing the site of the pseudoglottis For two years the laryngectomized patient spoke with a weak pharyngeal voice radiation offers hope in the treatment of carcinoma of the true cords, but it fails completely to improve unsatisfactory survival rates of patients with carcinoma in other parts of the larynx or laryngopharynx Shaw advocates the classical method of radical *en bloc* dissection of the larynx and cervical glands, together with removal of the sternocleidomastoid and omohyoid muscles, the internal jugular vein and the submaxillary gland Early diagnosis and early adequate surgical treatment remain the most powerful weapons for attacking cancer Radical surgical excision will never be the ultimate answer, but is the most effective single method available until biochemical control can be achieved

In an interesting and thorough article Goolden[106] states that the carcinogenic properties of ionizing radiation have been recognized for many years Radiation tumors that have developed in the pharynx and larynx are discussed Most radiation-induced tumors are squamous cell carcinomas Five cases of radiation cancer of the larynx have been reported in the literature These patients had irradiation for tuberculous adenitis and exophthalmic goiter In addition to these, 12 cases of postcricoid carcinoma after irradiation for thyrotoxicosis are reported Goolden classifies postcricoid carcinoma under pharyngeal tumors, but in our opinion, they could be equally as well classified as occurring in the larynx The latent interval between treatment and development of carcinoma ranged from ten to 35 years Goolden points out that with the new type of therapy now being used in irradiation there is less chance of development of post-radiation tumors

Henken[107] does not consider the primary diagnosis of carcinoma nor does he attempt the differential diagnosis He compares the current nomenclature of laryngeal carcinoma in the United States and the Netherlands The nomenclature is surprisingly similar basically in the large medical centers of both countries Based on classification the surgical indications are practically the same except more postoperative roentgenotherapy is administered abroad, and in some of the centers all patients are given a trial of roentgenotherapy preoperatively The comparative statistics are much more favorable in the United States than in the Netherlands, but the main possible to compare statistics and results and map out modes of treatment for various carcinomas of the larynx more accurately than we now can. Struben believes that carcinoma of the larynx should be treated only in special clinics in order to enable the staff to enlarge their experience and thus provide the patient with the best treatment possible.

The rare incidence of fibrosarcoma of the larynx, says Johnston,[103] can best be appreciated by comparison with the incidence of other cancerous tumors of the larynx. Figi reported four cases of sarcoma at the Mayo Clinic from 1910 to 1933 as contrasted with 713 cases of carcinoma of the larynx. Johnston reports three cases of fibrosarcoma and 686 cases of carcinoma seen between 1947 and 1956. The ratio of sarcoma to carcinoma is 1:117. Fibrosarcomas rarely metastasize, but when they do, extension is through blood vessels or infiltration. The tumor is usually smooth and rounded, and the diagnosis is made by microscopic examination of the tissue. Complete surgical removal is necessary for cure. Sarcomas are radioresistant. Johnston describes the therapy instituted in his cases with appropriate comments.

In a series of two articles Davis[104] presents first a lengthy historical sketch of carcinoma of the larynx followed by a detailed discussion of the incidence, etiologic factors, classification, pathologic processes and diagnosis. He emphasizes the necessity of repeated biopsies on clinically malignant-appearing lesions. In the second part of this article management of carcinoma of the larynx is well presented. The indications and technique for laryngofissure and laryngectomy are considered. Davis believes that there is a place for irradiation in the treatment of carcinoma of the larynx and quotes the views of numerous radiotherapists. In this article Davis has accomplished his objective to describe the essential facts of carcinoma of the larynx in such a way that the physician who is not a specialist in laryngology, encountering a patient with symptoms indicating the disease, would know how to proceed.

In a most comprehensive article Shaw[105] discusses all phases of cancer of the extrinsic larynx and laryngopharynx. Teletion fails, or there is a recurrence, surgical treatment is undertaken In the presence of cervical metastasis, surgical excision is advocated The result of this policy is that most patients who require surgical treatment have had full courses of deep Roentgen-ray therapy and devitalization of the skin The radical type of excision necessary in these patients creates such a defect that reconstruction is difficult Woods suggests insertion of a polyethylene sponge in a pocket created between skin flaps and prevertebral fascia A thick split skin graft is sewn around this polyfoam sponge The results obtained in such reconstruction of the pharynx have been most satisfactory

Hara[111] reports results of a study of the five-year survival rate of 38 patients with carcinoma of the larynx The symptomatology, diagnosis and pathology are considered, but only the essential features of the operative procedure are discussed This report is well presented and Hara makes a plea to endeavor to make people more conscious of the dangers of persistent hoarseness

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reason is that during the war years, Europe did not have the benefit of group comparisons and conferences This is an excellent article

Foxen[108] presents the results of a survey of 206 cases of carcinoma of the endolarynx treated by surgeons and radiotherapists during the past 23 years He briefly considers the anatomy, symptomatology, site of the disease, mobility, histology, treatment and prognosis Lack of mobility generally constitutes a firm surgical indication in operable cases Teleradiotherapy is the method of choice in mobile glottic cases Most patients in this series received some form of irradiation as their first and chief form of therapy Foxen reports that midcord carcinomas respond favorably to teleradiotherapy, however, cases of reduced mobility, and supraglottic and bilateral lesions give disappointing results with this type of therapy Foxen believes that laryngectomy unaccompanied by neck dissection is never indicated Apparently he does not appreciate the value of laryngofissure for limited cordal lesions, for he definitely states that "a laryngofissure operation is now considered most suitable for nonmalignant and premalignant conditions"

Trible[109] discusses the effect of preoperative *radiation on* subsequent operation in carcinoma of the larynx He believes that radiation has a place in the treatment of early lesions of the vocal cords but that all other lesions should be removed surgically Roentgen-ray in conventional dosage administered by the Coutard method does not adversely affect performance of laryngectomy, however, radiotherapy delays wound healing, increasing the duration of hospitalization, and frequently necessitates plastic procedures After higher doses of roentgen-ray radionecrosis may develop Comparison of the postoperative duration of hospitalization in a series having laryngectomy alone and a group having previous radiotherapy showed an average stay of 28 days for the former and 40 days for the latter The impression gained from reading this paper is that Trible is opposed to preoperative radiation

Woods[110] prefers a full course of deep Roentgen-ray therapy for all patients with carcinoma of the hypopharynx If radia-

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EXPERIMENTAL STUDIES IN FIXATION OF THE STAPES AND FENESTRA OVALIS *†

CESAR FERNANDEZ, M.D.,
GEORGE W. ALLEN, M.D.,
and
JOHN R. LINDSAY, M.D.,
Chicago, Ill.

Stapes mobilization, as put forward by Rosen[1] and further developed by many followers,[2-8] has been an important contribution to the surgical treatment of otosclerosis.

In cases of failure to mobilize the footplate of the stapes, Rosen[9] proposed the fenestra ovalis operation. Essentially, the procedure consists of creating an opening in the margin or body of the footplate of the stapes as close to the posterior crus as possible. Removal of the incus facilitates exposure of the footplate and creation of the fenestra. Rosen[10] has reported that normal or near-normal hearing was obtained in many cases, both when the ossicular chain remained intact and when the incus was removed. Consequently, Rosen[11] stated: "The Helmholtz concept of the transformer action of the intact ossicular chain is a *sufficient* but not a *necessary* condition for normal and near-normal hearing."

The concept that an intact physiological ossicular chain is a *necessary* condition for normal hearing prompted this investigation. The principles of the transformer action of the middle ear mechanism and the effects which follow injury of the ossicular chain, are fully explained in the comprehensive work of Wever and Lawrence,[12] Bekesy and Rosenblith,[13] Stuhlman,[14] Stevens and Davis,[15] and others.

The investigation to be reported here was undertaken for

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†From the Section of Otolaryngology, The University of Chicago.

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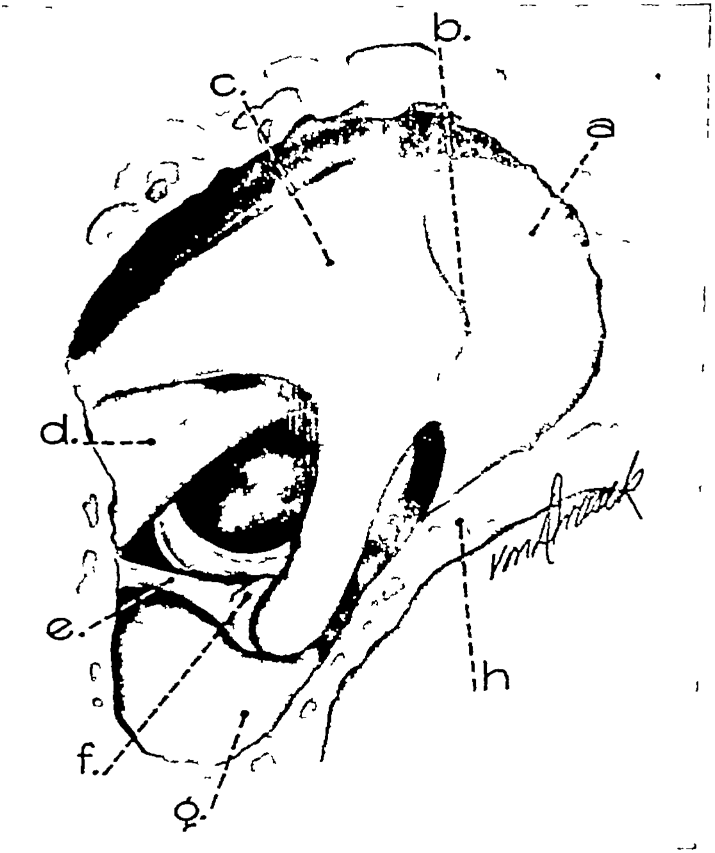

Fig 1 Freehand drawing of ossicular chain as seen after opening the attic a. malleus b malleoincudal articulation c incus d facial canal e tendon of stapedius muscle f head of the incus g tympanic cavity h. ridge of superior external canal

(CM) were measured by octaves from 125 to 8,000 c p s sine waves Thresholds are here defined after Pestalozza and Davis,[20] and maximum voltage as the voltage of CM for a predetermined set of the attenuator The input was fixed at an intensity sufficient to give an output of CM near the point of non-linearity Stimuli at higher intensity may produce, in the long process of measurements, undesirable fatigue effects For observing changes in action potentials (AP) 8,000 c p s tone pips were used the purpose of studying the effect of the fenestra ovalis, as described by Rosen,[10 11] on the transformer action of the middle ear mechanism in experimental animals This study may also help in the understanding of the results claimed by Rosen[10] but denied by others [8,16]

Thresholds and maximum voltage of both cochlear microphonics and action potentials were used as indices of the transformer action It is understood that the electrophysiological method of measuring sensitivity at the peripheral level is related but differs from the over-all sensitivity as determined by behavioral methods in animals or audiometric tests in human beings The electrophysiological method of recording cochlear responses is specific for the study of the mechanism of the peripheral ear, including the transformer action The behavioral or audiometric method is more suitable for studying the auditory system as a whole, which includes peripheral and central neural mechanisms

The decision to use thresholds and maximum voltage of cochlear microphonics as an index of the transformer action is justified by previous experience [12 17,18 19] Measurements of action potentials were included in this study, because they represent the final event of the peripheral mechanism

METHOD

The experiments were carried out on 19 cats anesthetized with pentobarbital sodium, 37 5 mg per kilo body weight, in a single dose

The operation was performed in three stages first, following removal of the mastoid cells and bone of the posterior and superior walls of the external canal, the round window niche was exposed An electrode of silver wire, enameled except for the flat tip, was allowed to rest on the membrane of the round window The opening in the bulla was sealed with dental cement An ear speculum coupled to a PDR-10 transducer by a plastic tube 80 mm long, was tightly attached to the external canal

Thresholds and maximum voltage for cochlear microphonics

250 c p s) improved by an average of 10 db while the other frequencies sometimes showed variations of a few decibels Sensitivity of AP was not modified

Commentary These experiments confirmed the results of Wever, Lawrence and Smith,[21] that is, opening of the middle ear cavity causes only minor changes in transmission For this reason we decided to use the cochlear responses given by the initial opening of the attic as the reference level, thus, in the course of this paper the results are generally expressed in terms of losses or gains in decibels relative to that reference

B *Injury to the Ossicular Chain*

The effect of injury to the ossicular chain has been fully explored in the past,[12] however, we reproduced those lesions which pertained to our aims

1 Disarticulation of Incudostapedial Joint Separation of incus from stapes was done by applying traction on the long process of the incus with a Shambaugh hook When traction was released, the incus always returned to contact with the stapes if the malleoincudal joint and posterior ligament had not been damaged Restoration of contact between the two bones was facilitated by sound stimuli To obtain a permanent gap it was necessary to rupture the posterior ligament and capsule of malleoincudal joint

A gap of 1 mm or more between incus and stapes produced a large impairment of thresholds and maximum voltage of both CM and AP A representative case is illustrated in Fig 2 *Curve A* represents the threshold shift of CM after disarticulation Low frequencies could not be differentiated from the background noises even at the highest intensity input In the middle range the losses were 40 to 60 db and for higher frequencies 30 to 40 db

Impairment of maximum voltage of CM also increased from high to low tones, the losses being between 20-30 db for high frequencies, and 30-40 db for the middle range This change in amplitude of CM for 2,000 c p s sine waves can be estimated from Record 2 The loss was 27 2 db , which represents about 95 per cent of the reference (Record 1)

The second stage of the operation consisted of exposing the attic so that incus and stapes with its footplate were widely visualized Fig 1 shows a freehand drawing of the ossicular chain, as seen under a Zeiss microscope (16X) The cochlear responses were measured again Some animals were used to study modifications of cochlear responses after various types of injury of the ossicular chain

The third stage of the operation was attachment of a device for mechanical fixation of the stapes and creation of the fenestra ovalis The device consisted of a small pulley with a thread which had a thin steel hook on one end and a scale pan for holding weights on the other end The hook was anchored to the neck of the stapes Cochlear responses were measured after adding to the scale pan weights from 10 to 40 gm Fenestration of the footplate was made with a sharp needle as close to the posterior crus as possible The effect of the fenestra ovalis was studied in four types of preparations

1 Normal ossicular chain

2 Injury of ossicular chain

3 Normal ossicular chain plus mechanical fixation of stapes

4 Injury of ossicular chain plus mechanical fixation of stapes

RESULTS

A *Cavity Effects*

The technique for fixation of stapes, making fenestra ovalis and other surgery of the ossicular chain required opening the attic This eliminates the volume elasticity of the middle ear cavity The question was raised as to whether there is a corresponding change in the cochlear responses The answer to this question is important in the final assessment of our results

Comparison of the results obtained before and after opening the attic showed that the opening produced modifications in thresholds of CM Low frequency sensitivity (125 and shown in Fig 2 *Curve B* represents the losses in sensitivity of CM after reconstruction, and Records 3 and 6 the recovery in voltage of CM and AP respectively The degree of recovery of these parameters only varied slightly from one animal to another

Commentary The results of these experiments showed that disarticulation of the incudostapedial joint was accompanied by a considerable loss in both sensitivity and amplitude of cochlear potentials This finding is particularly interesting, because as Wever and Lawrence[12] stated, "The loss just described is considerably greater than we should expect simply from the elimination of the transformer action of the middle ear mechanism, which we have found to average 28 db " The authors[12] gave two reasons for this effect one is that incus, malleus and tympanic membrane "are in the path of the incoming sound and cause both reflection and absorption of this sound to no good purpose" Wever, Lawrence, and Smith[21] measured the sensitivity of CM before and after disarticulation of the incudostapedial joint, and again after removal of incus, malleus and tympanic membrane After removal of the latter three structures, there was a recovery of about 15 db in the middle range of the threshold shift, produced by the incudostapedial disarticulation These experiments were repeated in two animals of the present series with the same qualitative result The other factor, which Wever and Lawrence[12] cited, is that "the sounds have more nearly equal access to both oval and round windows Their stimulating effects upon the inner ear tend to be counteractive" The contribution of this factor, as determined by Wever,[22] is about 12 db A third additional factor impairing responses is the loss of the lever ratio which, in the mechanical advantage of the ossicular chain of the cat, amounts to a factor of 2 5 [12]

2 *Removal of Incus* This injury produced similar, and in some animals a larger impairment of cochlear responses than disarticulation of the incudostapedial joint A representative case is illustrated in Fig 3 Threshold shift of CM was 42 db or more and that of AP was 55 db Amplitude of CM lost 23 db , which represents a reduction of 93 per cent of the

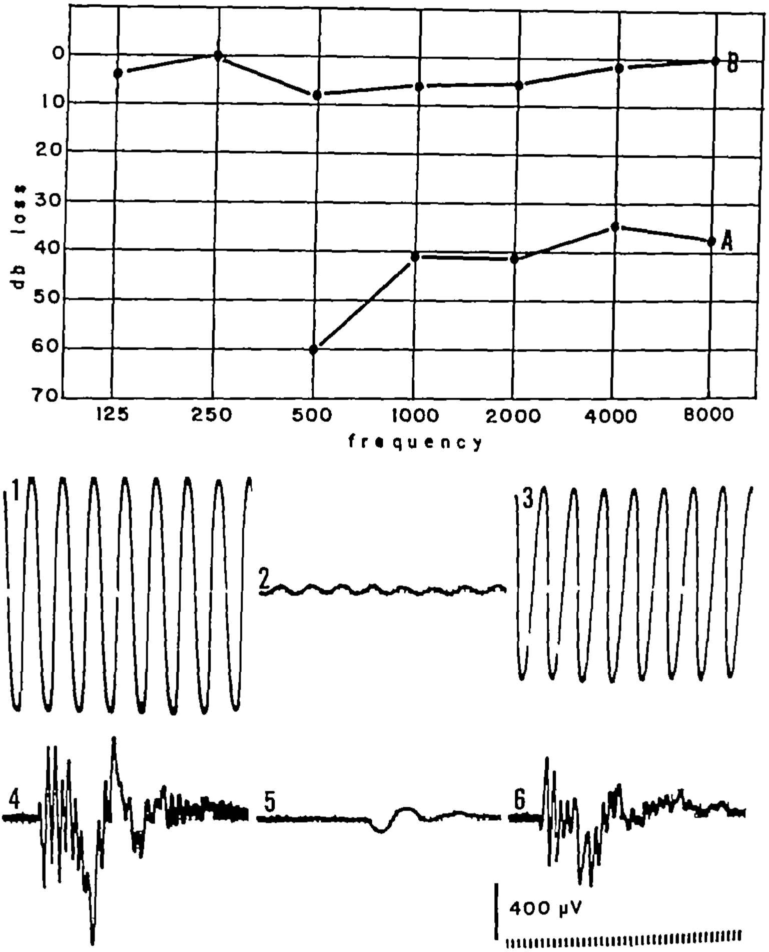

Fig 2 Cat A-479 Effect of disarticulation of incudostapedial joint followed by reconstruction Changes in thresholds of CM are represented by Curves A disarticulation of incudostapedial joint and B reconstruction Changes in amplitude of CM for 2000 c p s sine waves at 59 db above threshold are shown by Record 1 reference Record 2 disarticulation and Record 3 reconstruction The corresponding changes in amplitude of AP for 8000 c p s tone pips at 67 db above threshold are represented by Records 4 5 and 6 In this and following figures time calibration is 10 000 c p s

Changes in AP were considerable Threshold shifted as much as 55 db and amplitude was reduced to 30 per cent or less of the reference level, as Record 5 illustrates

A careful reconstruction of the ossicular chain by returning the incus to its normal position may produce nearly complete recovery of cochlear responses These findings are also

Wever et al,[21] which are supported by the experiments reported here, it is assumed that a gap in the ossicular chain of a human ear must produce equal or similar results

If the incus be removed and the malleus and tympanic membrane remain in their normal positions, they bring about one condition under which the transformer action of the middle ear mechanism cannot be fully restored In the fenestra ovalis operation, as proposed by Rosen,[10 11] the malleus and tympanic membrane are usually left in their normal positions, where they act as an attenuator of the incoming sound, the attenuation being of the order of 15 db [21] This loss cannot be recovered as long as the malleus and tympanic membrane remain in position and a gap exists between them and the inner ear

The recovery of cochlear responses after reconstruction of the ossicular chain (see Fig 2) is significant in two ways first, it supports the rationale of stapes mobilization[1-8] and similar operations[23] for otosclerosis, and also of tympanoplastic surgery The efficiency of these procedures depends upon success in reconstructing the transformer action of the ossicular chain as it normally exists, second, the posterior ligament of the incus and capsular ligaments of the incudostapedial and malleoincudal articulations seemed to play a minor role in transmission of sound All these ligaments can be broken and the incus displaced, upon reconstruction, however, the cochlear responses may return to the reference level This indicates that the functional properties of the incus during transmission of sound depend more on its contiguity with the malleus and stapes than on their attachments The importance of these attachments, as conceived by Helmholtz,[24] Dahmann[25] and others, seems to have been overemphasized

3 *Removal of Incus and Stapes* These experiments were done because they represent a modification of the fenestra ovalis operation, as proposed by Rosen [11] Removal of the stapes is equivalent to making a fenestra ovalis in the human being as large as the oval window

The results showed that the impairment of cochlear re-

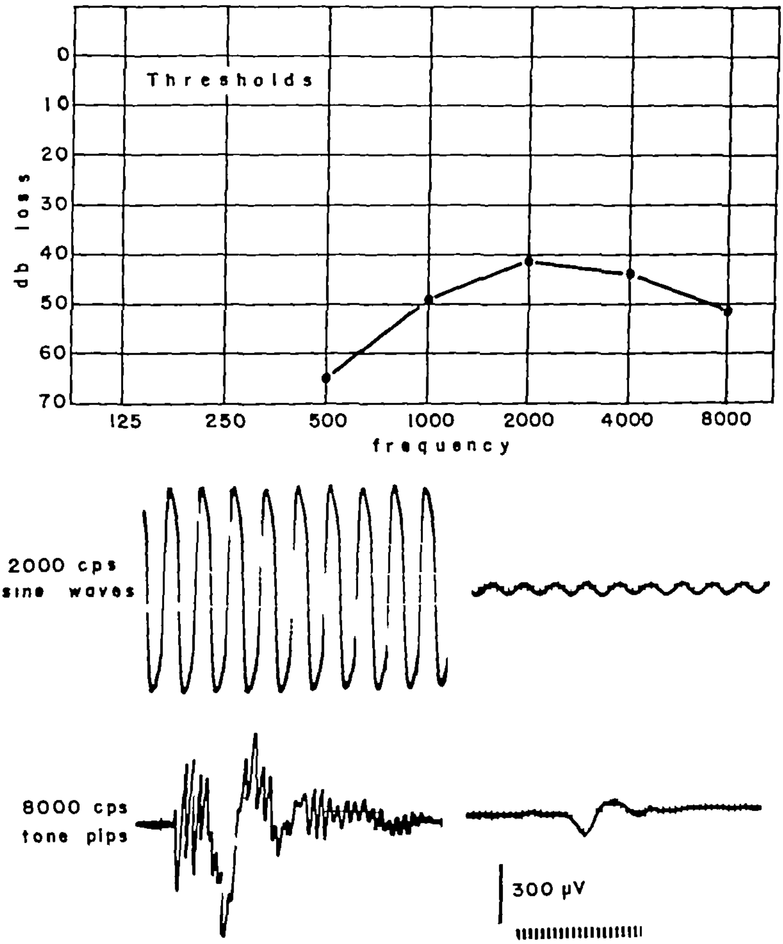

Fig 3 Cat A-455 Effect of removal of incus Thresholds of CM lost 42 db or more The records in the left column are references 2000 c.p s sine waves at 74 db above threshold of CM and 8 000 c p s tone pips at 76 db above threshold of AP The losses after removal of incus were 93 and 84 per cent respectively This can be estimated from the records on the right column

reference level Changes in amplitude of both CM and AP can be estimated from the records shown on the right column of Fig 3

Commentary The impairment of responses following removal of the incus is due to the same factors that produce a threshold shift when the incudostapedial joint is simply disarticulated From the results of Wever and Lawrence,[12] and

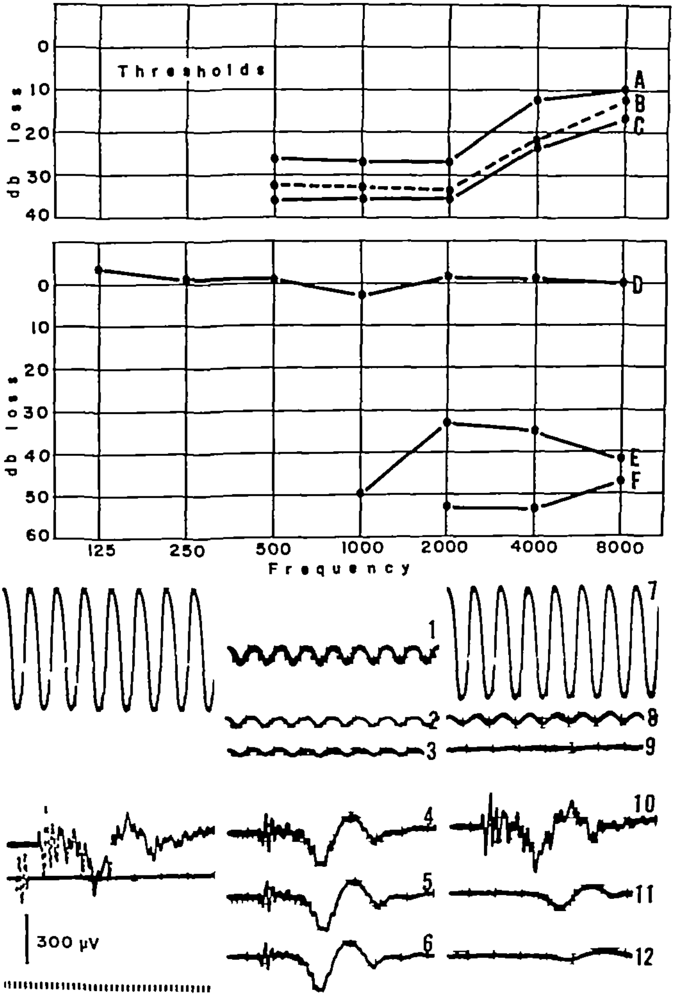

Fig 4 Cat A-454 Effect of simple mechanical fixation of stapes Records in left column are reference for amplitude of CM and AP for 2 000 c p s sine waves at 66 db above threshold and 8 000 c p s tone pips at 67 db above threshold respectively Curves and other records represent the following Fixation of stapes with 10 gm Curve A and Records 1 and 4 Fixation with 20 gm Curve B and Records 2 and 5 Fixation with 30 gm Curve C and Records 3 and 6 Removal of weight. Curve D and Records 7 and 10 Removal of incus without fixation of stapes Curve E and Records 8 and 11 Finally fixation of stapes without incus Curve F and Records 9 and 12

sponses due to ablation of incus and stapes together was of the same order of magnitude as removal of incus alone

Commentary These experiments indicate that a fenestra ovalis of the size of the oval window, leaving malleus and tympanic membrane undisturbed, produces a loss in cochlear responses larger than simple elimination of the transformer action At least some of the reasons for this impairment are those just mentioned

This or similar procedures had been used in the past for surgical treatment of otosclerosis The approach proved to be unsatisfactory and was abandoned The reasons for its failure are now understood

C Mechanical Fixation of Stapes

The mechanical device for fixation of the stapes was arranged in such a manner that the direction of the pulling force acted approximately parallel to the main axis of the anterior crus Avoiding contact of thread and/or hook with surrounding tissues reduced frictional forces to a minimum Because of the anatomical arrangement and direction of acting force, we assumed that the anterior region of the footplate was retracted appreciably

The weight of hook, thread and scale pan was 0 8 gm Attachment of this mechanical device produced minor losses in both thresholds and maximum voltage of cochlear responses Most of the experiments in mechanical fixation made use of a maximum weight of 30 gm This criterion was adopted because of limitations imposed by resistance of the stapes which usually broke with a weight of 40 gm

Addition of weights in steps of 10 gm each produced a characteristic pattern in cochlear responses, as Fig 4 illustrates *Curves A, B and C* represent threshold shifts of CM after adding 10, 20 and 30 gm respectively The impairment increased from high to low tones Fixation with 30 or 40 gm produced a loss of 15 to 20 db for high frequencies, 35 to 40 db for the middle range, and no responses were seen for the low frequencies Changes in maximum voltage of CM are illustrated in Records 1, 2 and 3, which correspond to the fixation of the stapes with incus removed represents the combined action of several factors

a. Removal of incus eliminates the transformer action of the middle ear mechanism which accounts for 28 db

b Malleus and tympanic membrane absorb and reflect acoustic energy This shifts the sensitivity curve to about 40 db loss

c Mechanical fixation of stapes increases stiffness reactance and frictional resistance which add to the previous factors

d The lever ratio of ossicular chain is definitely lost

e Mechanical fixation of the stapes produces a blocking effect in the oval window and consequently the sound pressure is applied only in one window, *i e*, the round window Since there is now no point of pressure discharge, the mass displacement of cochlear fluids necessary for stimulation of sensory organs either cannot take place or is largely reduced

Combination of all these factors produces the residual hearing illustrated by *Curve F* (sensitivity of CM) and Records 9 (amplitude of CM) and 12 (amplitude of AP) of Fig 4

This interpretation may be considered to be a restatement of that given by Wever[22] after several experiments on blocking the round and oval windows

D The Fenestra Ovalis

Exposure of the footplate of the stapes in the cat is a minor surgical problem A wide view of it can be obtained by removing the attic bone as close to the posterior ligament of the incus as possible and drilling down the facial canal

The fenestra ovalis was made with a steel wire which was sharpened with sand paper to a diameter of about 100 microns at the tip The holes were irregular in shape and of a size larger than the stylet Sometimes the fenestration produced fractures which occasionally extended to the margins of the footplate The fenestra ovalis was preferably made near effect of fixation upon CM for 2,000 c p s with 10, 20 and 30 gm , respectively The losses were 5 to 10 db for high frequencies and 25 to 30 for the middle range

The average loss in thresholds of AP after fixation with 30 gm was 16 db Changes in amplitude can be estimated by the Records 4, 5 and 6, which correspond to the effect of 10, 20 and 30 gm , respectively Notice that the amplitude of AP was little affected by the increasing weight

All the curves and records shown in Fig 4 belong to one animal, which was considered to be representative of this series Slight variations in both sensitivity and maximum voltage of cochlear responses were found from animal to animal

The question whether fixation of the stapes may have some traumatic consequences was explored in many cases by removing weight and mechanical device After this the responses fully recovered the reference level, as Fig 4 illustrates *Curve D* corresponds to sensitivity of CM, Record 7 to maximum voltage of CM at 2,000 c p s and Record 10 that of AP at 8,000 c p s

The impairment produced by fixation of the stapes with 30 gm increased considerably after removal of the incus The losses in sensitivity and amplitude of both CM and AP were consistently larger than 50 db These findings are shown in Fig 4 *Curve E* (sensitivity of CM), and Records 8 (amplitude of CM) and 11 (amplitude of AP) correspond to the effect of removal of incus only Subsequent impairment of fixing stapes with 30 gm is shown by *Curve F* and Records 9 and 12

Commentary The results on simple mechanical fixation of the stapes without other lesions of the ossicular chain, confirmed the findings of Smith[20] The increasing impairment from high to low tones is due to "the fact that fixation of stapes adds a great amount of stiffness as well as frictional resistance to the moving system "[12]

The profound impairment in sensitivity of CM following

Commentary These observations are interesting because they showed that the footplate is very brittle The perforation with a stylet may produce fractures which extend to the margins, and both size and shape of the hole are unpredictable It is possible that in human subjects the fenestra ovalis may produce fractures which act as a stapes mobilization

The fact that the fenestra ovalis produced a stream of perilymph which filled the oval window niche is important because this fluid and the fluid of the inner ear make a continuous medium through the fenestra The significance of this observation will be presented in a following paragraph

E Effects of Fenestra Ovalis

1 Normal Preparations

The fenestra ovalis performed in a normal ossicular chain in general produced minor changes in cochlear responses In some animals the reference level was not modified during 1 to 2 hours of observation, while in others sensitivity of CM may lose 10 db at some frequencies These changes were observed in low and middle tones while high frequencies consistently remained unchanged

Commentary These preparations are important because they showed that a careful performance of the fenestra ovalis was not accompanied by immediate damage to the sensory organs This is true only for acute preparations The loss of as much as 10 db, which was observed in some frequencies of some animals, may be related to fracture of the footplate and accumulation of fluid in the oval window and tympanic cavity

2 Injury of Ossicular Chain Without Fixation of Stapes

The procedure consisted of creating a fenestra ovalis first and then severing the ossicular chain in several ways, or vice versa

The results were essentially the same as in the series in which the ossicular chain was damaged without fenestration of the footplate A case is illustrated in Fig 6 Curves *A* and *E* represent thresholds and maximum voltage of CM after the posterior crus, but in some animals it was located in the center In many experiments it was enlarged once or twice in order to correlate its size with cochlear responses The fenestra ovalis was always followed by a stream of perilymph which filled the oval window niche and sometimes ran into the attic and/or tympanic cavity In our experiments it was not possible to keep the oval window niche free of perilymph longer than a few seconds

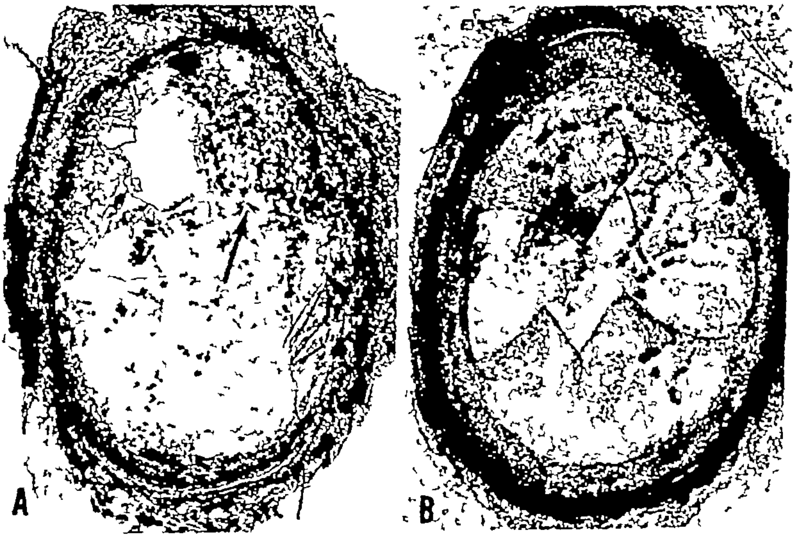

Fig 5 Samples of fenestra ovalis made in the footplate of stapes in the cat A Small fenestra after perforating the footplate just once Arrow points to a fracture which extends to the margin Enlargement of fenestra ovalis produced generally holes of the same shape but associated with several fractures B This unusual fenestra ovalis was found in one case The hole was enlarged twice Unstained X50

In six animals the temporal bones were removed at the end of the experiment and fixed in Heidenhain-Susa solution Subsequently the stapes and frame of the oval window were carefully dissected and mounted in thick Canada balsam for photographic reproductions and microscopic measurements of the fenestra ovalis Fig 5 shows two different footplates with two kinds of fenestrae, as seen from the vestibular side The area of the fenestra ovalis varied from 0 075 mm^2 (Fig 4-A) to 0 320 mm^2 (Fig 4-B) ovalis in a mobile stapes did not restore the transformer action which had been altered by injury to the ossicular chain Even after removal of the malleus and tympanic membrane, the losses exceeded those produced by simple elimination of the transformer action of the middle ear mechanism The cause of impairment following injury of the ossicular chain has already been explained

3 Ossicular Chain Intact with Fixation of Stapes

These conditions are shown in Fig 7 The freehand drawing from a preparation shows undamaged ossicular chain, the hook anchored on the neck of stapes and a simplified fenestra ovalis near the posterior crus

The impairment of thresholds and maximum voltage of both CM and AP produced by mechanical fixation of the stapes remained essentially unchanged after the fenestra ovalis Some animals showed improvement of about 5 db for thresholds of CM, others, like the one illustrated in Fig 8, presented losses of as much as 10 db *Curve G* represents threshold shift of CM after fixation of the stapes, and *Curve H* the further shift following the fenestra ovalis The corresponding changes in maximum voltage of CM for 1,000 c p s are shown on Records 4 and 5, and those for 4,000 c p s in Records 6 and 7 Records 8 and 9 illustrate changes in AP Notice in Fig 8 that cochlear responses recovered the reference level after removal of weight This is shown by *Curve I* and Records 10, 11 and 12

The size and location of the fenestra ovalis did not produce changes which were different from those already described

After fixing the stapes with 30 gm and creating the fenestra ovalis, the attic was closed with dental cement in several animals The results showed impairment similar to that seen with attic open

Commentary This series clearly demonstrated that the fenestra ovalis did not restore the losses produced by fixation of the stapes, thereby indicating that the transformer action of the middle ear mechanism is a necessary condition for normal hearing as measured at the peripheral level

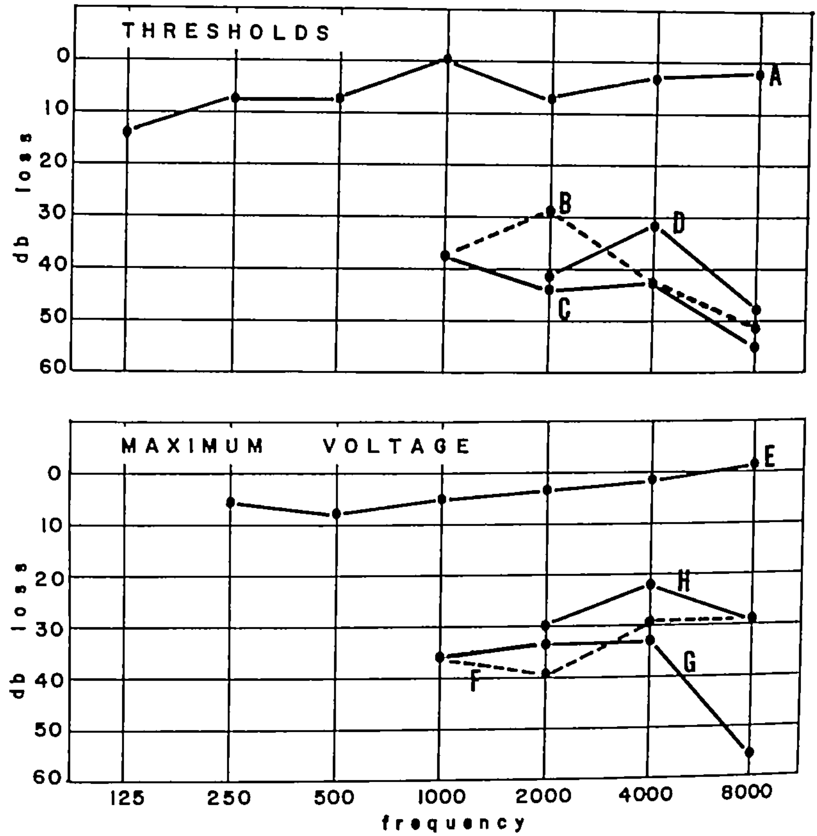

Fig 6 Cat A-403 Effect of fenestra ovalis with injury to the ossicular chain Stapes not fixed Curves A and E represent thresholds and maximum voltage of CM after fenestra ovalis alone Disarticulation of incudo-stapedial joint produced losses represented by Curves B and F respectively Removal of incus Curves C and G and removal of remaining malleus and tympanic membrane Curves D and H

the fenestra ovalis alone Disarticulation of the incudo-stapedial joint produced a threshold shift of CM of about 40 db or more for most frequencies (*Curve B*) These losses increased when the incus was removed (*Curve C*) Finally, when malleus and tympanic membrane were extirpated thresholds improved (*Curve D*), however, the final loss exceeded 40 db The corresponding changes in amplitude of CM are shown in *Curves F, G* and *H* Sensitivity and amplitude of AP followed a similar pattern

Commentary This series demonstrated that a fenestra

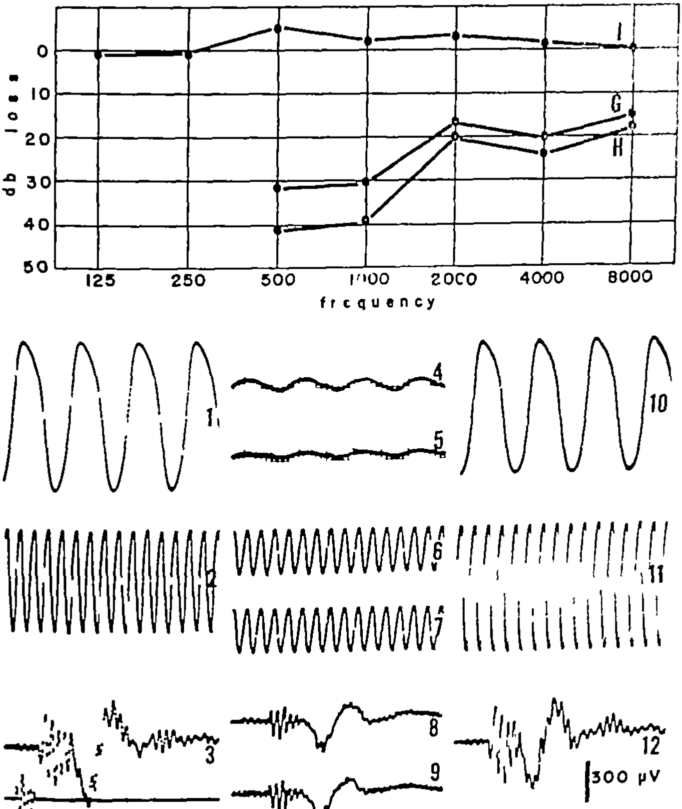

Fig 8 Cat A-458 Effect of fenestra ovalis following fixation of stapes with 30 gm Ossicular chain was not damaged Record 1 reference amplitude of CM for 1 000 c p s sine waves at 67 db above threshold Record 2 reference for 4 000 c p s at 59 db above threshold and Record 3 reference of AP for 8 000 c p s tone pips at 71 db above threshold Curves for thresholds of CM and other records represent the following Fixation of stapes with 30 gm Curve G and Records 4 6 and 8 After fenestra ovalis Curve H and Records 5 7 and 9 Removal of weight, Curve I and Records 10 11 and 12 Notice that amplitude of CM for 4 000 c p s is larger than the reference by 1 8 db

4 *Removal of Incus and Fixation of Stapes*

Fig 9 is a freehand drawing of the ossicular chain after removal of incus and creation of the fenestra ovalis As demonstrated before, removal of incus alone produced a considerable loss in thresholds and maximum voltage of both CM and AP After removal of incus and fixation of stapes, the impairment exceeded 50 db loss for all frequencies In

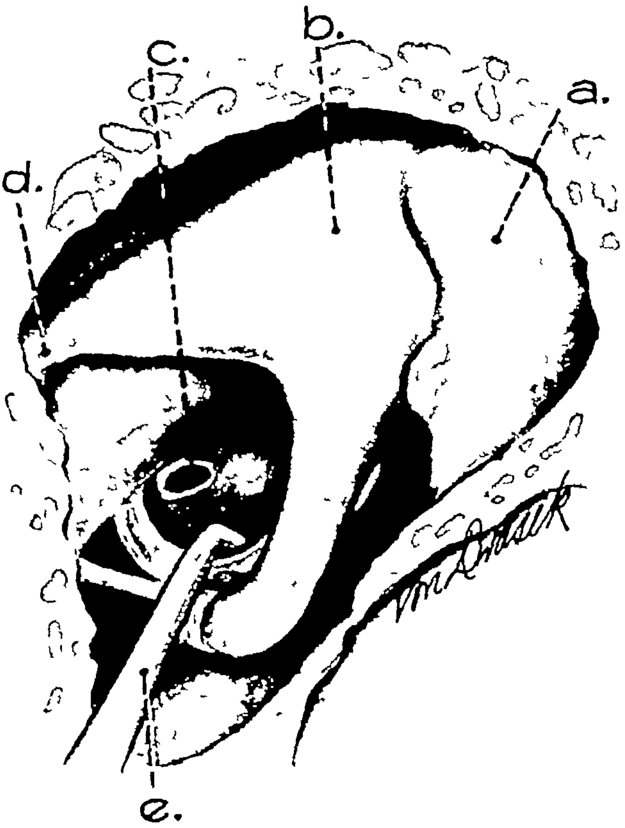

Fig 7 Freehand drawing of the ossicular chain showing the placement of hook for mechanical fixation of stapes and a simplified fenestra ovalis. A. malleus b incus c fenestra ovalis d posterior ligament of incus e hook for mechanical fixation of stapes

The question of whether fixing the stapes and creating the fenestra ovalis may produce some injury in the conductive mechanism and/or sensory organs was ruled out because cochlear responses recovered the reference level after removal of weight

Factors such as attic open or attic closed did not modify the impairment already established Similarly size and location of fenestra ovalis seemed not to be critical factors in this type of preparation

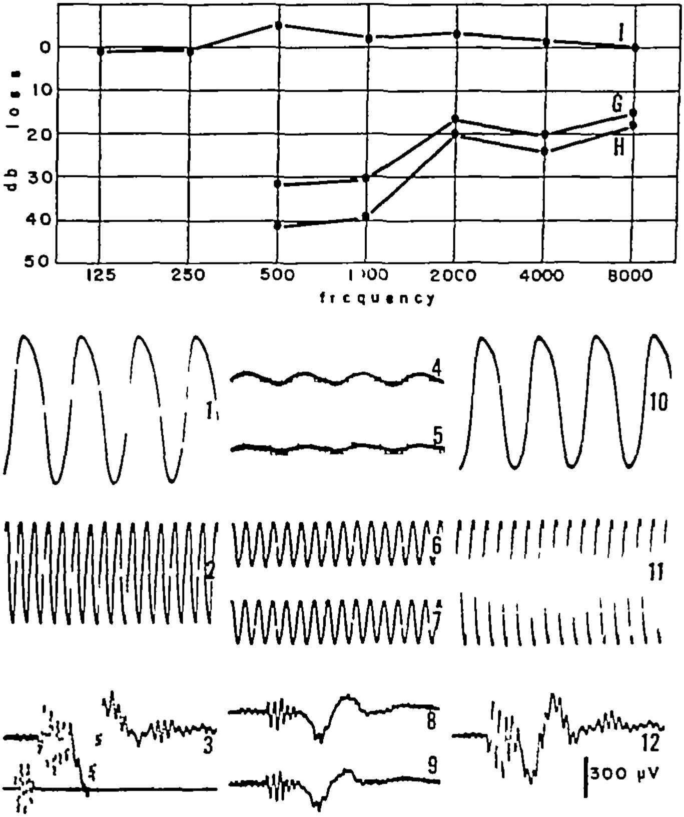

Fig 8 Cat A 458 Effect of fenestra ovalis following fixation of stapes with 30 gm Ossicular chain was not damaged Record 1 reference amplitude of CM for 1 000 c p s sine waves at 67 db above threshold Record 2 reference for 4 000 c p s at 59 db above threshold and Record 3 reference of AP for 8 000 c p s tone pips at 71 db above threshold Curves for thresholds of CM and other records represent the following Fixation of stapes with 30 gm Curve G and Records 4 6 and 8 After fenestra ovalis Curve H and Records 5 7 and 9 Removal of weight Curve I and Records 10 11 and 12 Notice that amplitude of CM for 4 000 c p s is larger than the reference by 1 8 db

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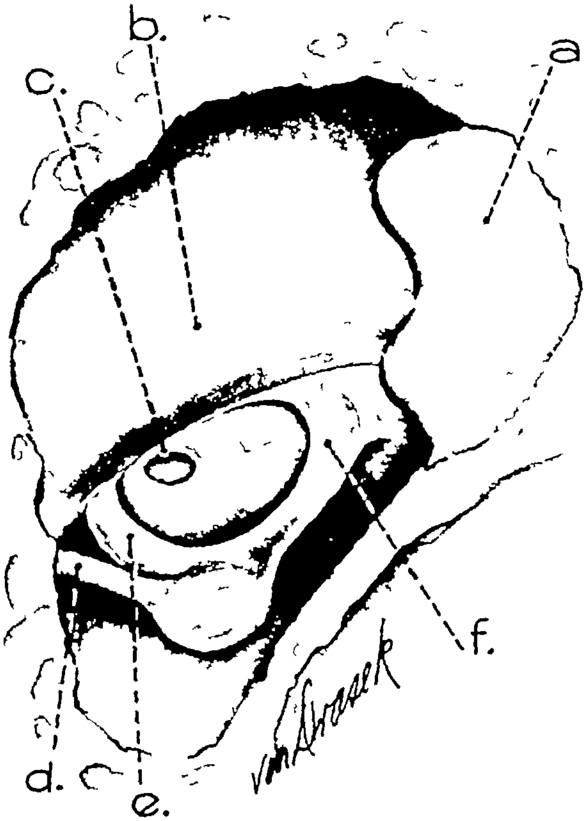

Fig 9 Freehand drawing of ossicular chain after removal of incus For simplicity hook for mechanical fixation was not included a malleus b facial canal c simplified fenestra ovalis d tendon of stapedius muscle e posterior crus of stapes f anterior crus of stapes

general, this result was favorably modified by the fenestra ovalis

Changes in thresholds of CM of a representative case are illustrated in Fig 10 *Curve J* shows the threshold shift after fixation of stapes alone, and *Curve K* that after removal of incus alone When removal of the incus was followed by fixation of the stapes thresholds shifted to *Curve L* After the fenestra ovalis was created, thresholds improved to *Curve M*, and when the fenestra was enlarged, thresholds showed

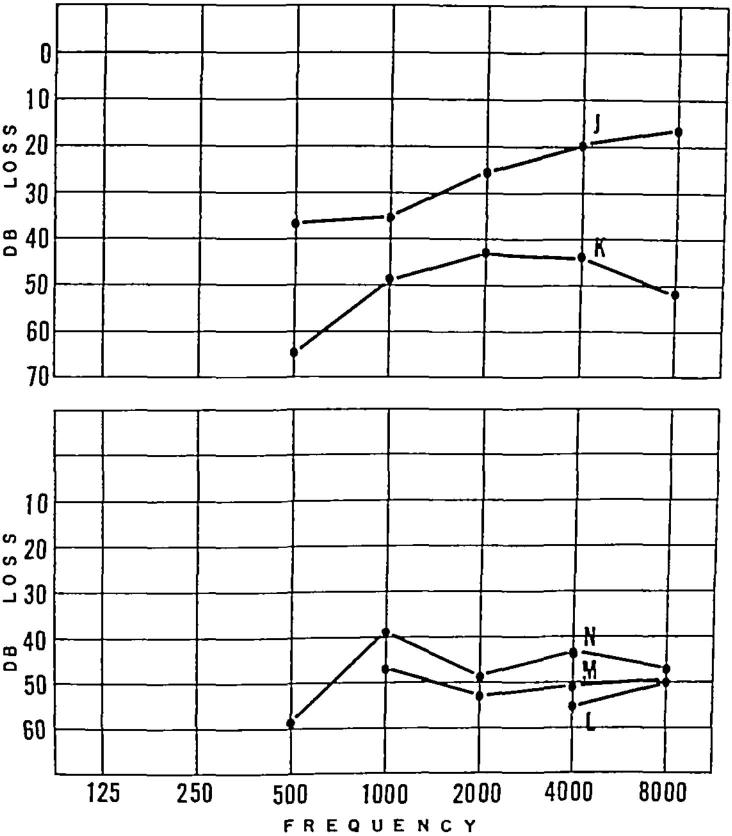

Fig 10 Cat A-455 Effect of fenestra ovalis on thresholds of CM after fixation of stapes and removal of incus. Fixation of stapes with 30 gm. Curve J Incus removed without fixation of stapes Curve K. Incus removed plus fixation of stapes with 30 gm Curve L Curve M, fenestra *ovalis plus incus removed and stapes fixed Curve N the fenestra was* enlarged twice

further improvement, *Curve N* Final losses exceeded the 40 db level

Threshold shift of AP produced by fixation of the stapes and removal of the incus was also favorably modified, but the final loss was about the 60 db level

Changes in amplitude of both CM and AP can be estimated from the records presented in Fig 11 The fenestra ovalis improved the losses produced by fixation of the stapes and

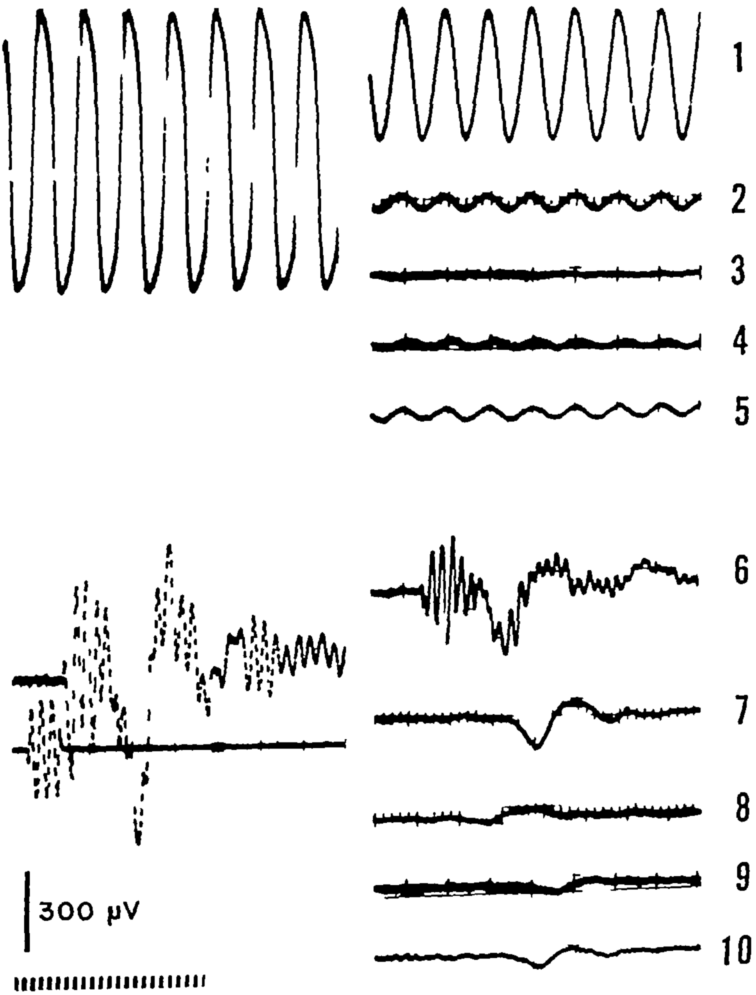

Fig 11 Cat A-455 Effect of fenestra ovalis on amplitude of CM and AP The records on left column are reference 2 000 c p s sine waves at 74 db above threshold and 8 000 c p s tone pips at 76 db above threshold Records 1 and 6 fixation of stapes with 30 gm Records 2 and 7 removal of incus without fixation of stapes Records 3 and 8 removal of incus and fixation of stapes The hump in Record 8 is an artefact Records 4 and 9 fenestra ovalis plus incus removed and stapes fixed Records 5 and 10 the fenestra ovalis was enlarged twice

removal of the incus by a few decibels Nevertheless, the losses were 90 per cent or more of the reference

When the sound stimuli were applied through the attic instead of the external ear the losses already described were sometimes decreased by a few decibels A similar effect was obtained by removing both malleus and tympanic membrane or by creating a perforation in the tympanic membrane

Commentary The losses produced by fixation of the stapes and removal of the incus were definitely decreased by a fenestra ovalis, however, the final loss remained larger than 40 db As in the previous series these findings do not support the proposition of Rosen[10,11]

The further improvement that was observed after removal of malleus and tympanic membrane, or after creating a perforation in the tympanic membrane, or when sound was introduced through the attic is due to the same condition that is, elimination of attenuating effect produced by the presence of malleus and tympanic membrane

The improvement of cochlear responses by the fenestra ovalis after fixation of the stapes and removal of the incus is more difficult to explain When the stapes is fixed and the incus removed, incoming sound has access mainly to the round window In other words, stiffness and frictional resistance are added to the stapes and, furthermore, mobilization of inner ear fluids is largely reduced because of the blocking effect[illegible] Now, the fenestra ovalis produces a stream of perilymph which fills the oval window niche, thereby the surface of perilymph reestablishes the area of this window Inner ear fluids and fluid in the oval window niche make a continuous medium through the fenestra ovalis[illegible] As a consequence the blocking of the oval window is eliminated, and stiffness and frictional resistance no longer play a role at this level The fenestra ovalis seemed to produce the same effect as in the series where the incus was removed, but the stapes was not fixed In both series the incoming sound has access to both windows and their counteractive effects will largely depend upon their phase relation

In the series where the stapes was fixed and ossicular chain remained intact the fenestra ovalis has no favorable effect, because sound is mainly conducted through on intact but overloaded ossicular chain This overloading is not modified by the fenestra ovalis former action of the middle ear mechanism has been altered, therefore, the proposition of Rosen,[10,11] that "the transformer action of the intact ossicular chain is a sufficient but not a necessary condition for normal and near-normal hearing," is not supported by these experiments

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OTOLOGIC EVALUATION IN CLEFT PALATE PATIENTS *†

EMANUEL M. SKOLNIK, M.D.,
Chicago, Ill.

The increasing concern for the complex and many faceted needs of the child with a cleft lip and palate, particularly in the domain of speech disorders, has necessitated the organization of a carefully designed integrated program of diverse professional talents striving toward a common goal—effective care on a longitudinal basis to obtain superior functional results. The otolaryngologist, in particular, is possessed of the proper grounding in the surgical anatomic and physiologic nature of the contiguous structures to render a most valuable service in the total rehabilitation of such a patient.

Since good hearing is essential to learning to speak, it is obvious that any hearing loss due to diseases of the ear is an obstacle to the patient's acquisition of good speech and is of primary concern to all who are engaged in the care of the cleft palate patient. The split in the velum alters physiologically the muscles related to the Eustachian tube, thus making the child vulnerable to frequent attacks of otitis media.

The tonsil and adenoid problem, so often the subject of controversy in the case of a normal child, deserves judicious evaluation when the child has a cleft palate since the lymphatic structures are an integral component of the velopharyngeal mechanism for the development of normal speech.

Congenital deformities of the external ear and nose with resultant nasal obstruction, as well as the type of cleft and status of the patient, may play a significant role in the final analysis of the auditory state; however, the management of the multiple phase problem of auditory deficiency relative to

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‡Figures and photographs are from the files of the Cleft Palate Center of the University of Illinois College of Medicine.

the condition of a cleft palate is mainly one of hearing loss It is essential to know whether the loss of hearing is progressive and whether the speech development will be restricted by the hearing deficit

The purpose of this paper is to report the results of a survey of the ear pathology and audiological findings in patients with clefts of the lip and palate, and to analyze the factors related to the pathogenesis of ear disease in this congenital anomaly

HISTORICAL

In 1878, Alt[1] reported on the "Cure of Deafmutism by Successful Treatment of Otorrhea and Congenital Cleft Palate" Thorington,[2] in 1892, reported a case of "almost total destruction of the velum palati corrected by an artificial soft palate, producing not only greatly improved speech, but an immediate increase of audition" Then in 1904, "drainage of milk through the ear in an infant with congenital cleft palate" was reported by Variot [3]

The importance of good hearing in the phonetic rehabilitation of cleft palate patients was recognized early In 1893, Gutzmann[4] observed that about half of his cleft palate patients had hearing disturbances which accounted for a frequent failure of speech therapy Lannois[5] was probably the first to approach the problem of the status of the middle ear relative to cleft palate in 1901 Brunck,[6] in 1906, emphasized the need for a thorough otolaryngological examination in the phonetic correction of cleft palate patients because of the high percentage of inflammatory changes involving the upper airways and middle ear of these patients Introducing the term "submucous cleft palate," and making a thorough investigation of this congenital anomaly, Kelly,[7] an otolaryngologist, in 1910 reported that 15 of 19 cases had ear difficulty associated with nasal catarrh Rendu[8] associated cleft palate with congenital atresia of both external auditory canals and rudimentary auricles in 1912 Borel,[9] in her study on the physiology of phonation and speech therapy in cleft palate patients, discussed otogenic phonetic disturbances, their correction and auditory re-education

Pagnamenta[10] made an analysis of 150 postoperative cleft palate patients, and found that 30 per cent had hearing loss, however, he also observed that the severity of the cleft was parallel to the increase in severity of hearing loss Seeler[11] stressed the importance of systematic speech therapy in cleft palate patients directed toward improving the efficiency of the palatal and tubal musculature, and the avoidance of persistent closure of the tube Segre[12] studied the pressure changes in the middle ear of cleft palate patients during respiration and deglutition and maintained that in these patients the tubal opening has a paradoxical behavior—usually opens and closes during swallowing Opposite conclusions were reached by Meissner,[13] who made an analysis of 213 cleft palate patients whose ages varied between 10 and 35 years He found hearing disturbances in 27 per cent of his cases, but only 17 per cent of them had perfectly normal ears The basis for these findings is a persistent closure of the Eustachian tube due to physiopathologic changes in the velotubal musculature No relationship was found by Meissner between ear pathology and the severity of the cleft

✓Beatty,[14] in dealing with pre- and postoperative management of cleft palate patients, recognized that seven per cent of his patients had infections of the ear or sinuses while under surgical observation He pointed out how remarkable is the small percentage of ear and sinus disease in these patients, considering the disturbance of normal physiology of the nasal and oral cavities, often in association with malnutrition, dehydration and improper feeding methods

More recently, Sataloff and Frazer[15] analyzed 30 children with cleft palate, and related the very high incidence of ear pathology and hearing loss (90 per cent) to hyperplasia of tonsils and adenoids They suggested early adenoidectomy in infancy to preserve the hearing Nassy,[16] of the Netherlands, studied 70 children and 40 adults with cleft palate and found that 61 per cent of them had hearing disorders and ear pathology He suggests a disturbance of the function of the

Eustachian tube and that the frequency of ear disorders depends on the size of the cleft He made a plea for early closure of the cleft, speech training and regular treatment of ear, nose and throat pathology Halfond and Ballenger[17] analyzed the audiological and otological findings of 69 cleft palate patients and found that 50 per cent or more have hearing loss, however, no definite relationship could be established between hearing loss and the type and width of the cleft, surgical or non-surgical closure, nasal pathology, or hyperplasia of lymphoid tissue

METHOD OF APPROACH TO ANALYSIS

This study was carried out over a period of eight years and the data were derived from a study of hundreds of patients with clefts of the lip and palate Four hundred and one of these individuals received a complete otolaryngological examination, and constitute the basis for this investigation and presentation

The otolaryngological examination included the following survey

A History pertaining to

1 Previous ear disease

2 Age of first attack and frequency of ear infection

3 Frequency of upper respiratory infections

4 Frequency of sore throat (tonsillitis)

5 Relationship of upper respiratory infection and sore throat to ear infection

6 Surgical removal of tonsils and adenoids, age of operation and significance relative to ear infection

7 Presence of allergic factors of the upper head space

8 Relationship of growth of individual to ear infection

9 Contagious diseases and their relationship to ear infection

10 Closure of the palate and the relationship to ear infection

11 Insertion of a speech aid and the relationship to upper respiratory infections, sore throat and ear infection

12 Hearing loss, onset and course

B Otological evaluation

1 Configuration of auricles

2 Patency and configuration of external auditory canals

3 Tympanic membranes—

a Landmarks and light reflex
b Evidence of retraction
c Scarring
d Perforations (site and size) and
e Nature and amount of secretion

C Rhinological evaluation

1 External configuration (dorsum, alae, columella, nares)

2 Condition of the vestibule

3 Septal deformity (deviations, ridges, spurs)

4 Color of mucosa and size and resilience of turbinates

5 Presence of abnormal secretions

6 Patency of airway

D Pharyngolaryngological evaluation

1 Type of cleft palate, width, and condition of adjacent tissues

2 Neuromuscular function of velum and pharynx

3 Presence, size, site, and condition of tonsils and adenoids

4 Relationship of tonsils to movement of soft palate

5 Relationship of tonsils to dimension of oro-pharynx

6 Relationship of nasopharyngeal lymphoid tissue and nasal obstruction

7 Evidence of laryngeal anomalies

8 Size and position of tongue (glossoptosis)

9 Configuration, color and movement of pharyngeal and laryngeal structures

10 The airway

E Laboratory procedures

1 X-ray studies of mastoids (Schuller-Law, Stenver, Towne and Mayer's view) and sinuses (Caldwell, Water and laterals) was carried out when pathology was suspected

2 Laminographic studies of the nose and nasopharynx when indicated

F Functional examination

1 Vestibular evaluation performed in presence of severe or perceptive hearing loss

2 Hearing evaluation in patients with—

- *a* Congenital anomalies of the ear
- *b* History of recurrent ear infection
- *c* Evidence of middle ear pathology
- *d* History of contagious diseases that might relate to the ears
- *e* Clinical evidence of inner ear dysfunction

3 The hearing evaluation included—

- *a* Conversational and whispered voice
- *b* Tuning forks
- *c* Pure tone audiometry
- *d* Speech reception threshold and discrimination tests (binaural in free field and monaural with ear phones) when advisable

Hearing evaluation in preschool children was performed by conditioning the child to execute a certain movement when pure tones, the name of toys, or low ("go") and high pitched ("sh") sounds were transmitted to him through a loudspeaker or ear phones By transmitting these sounds at different loudness levels a fairly accurate hearing evaluation could be made If a child was severely deaf, reflexes were studied when producing very loud noises (tom-tom, bells, whistles, etc) In instances of severe mental retardation, or in brain injured children, the responses to auditory stimulation during electroencephalography were observed The psychogalvanic skin resistance test was employed only as a control when advisable

To further document data referable to growth and development of the head associated with this anomaly, cephalometric roentgenography is employed The instrument for oriented cephalometric roentgenography consists of a firmly-based head-positioning device and two X-ray tubes in fixed relationship to the head-positioner (see Fig 1) This arrangement provides a constant position of the head in relation to the source of X-rays, therefore, it becomes possible to reproduce the same lateral and postero-anterior views of the head at desired intervals The resultant films are then placed on a trans-illuminated tracing table and covered with thin tracing paper The bony structures visible on the film, as well as the outlines of the soft tissue profile, the pharynx, soft palate and the tongue are traced onto the paper Where it is desired

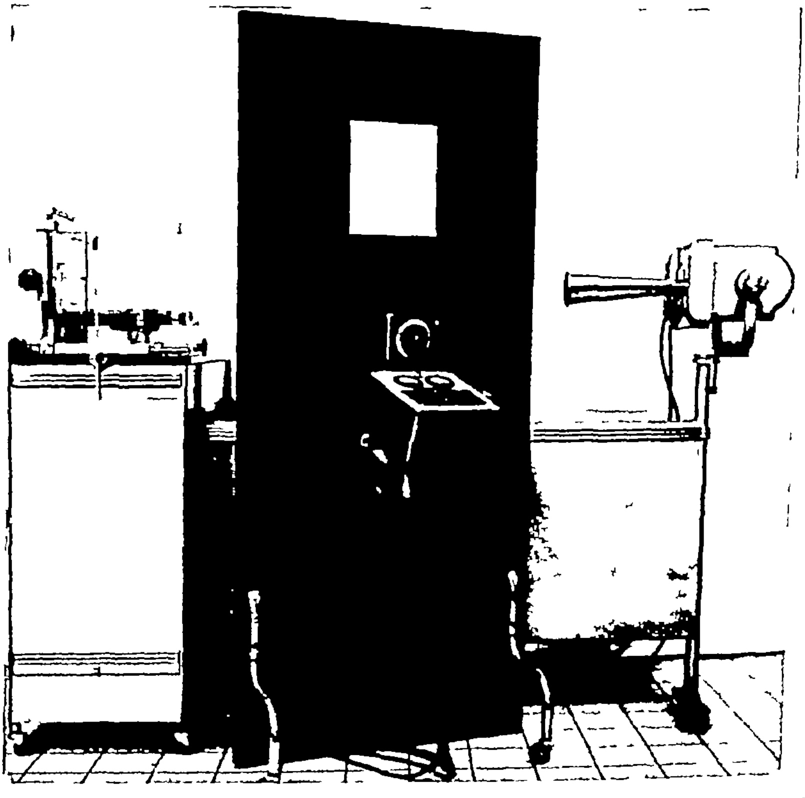

Fig 1 Specially designed cephalometer The X-ray tube for the frontal film is concealed within the cabinet beneath the head holding device

to study the changes incident to growth or the movements during phonation, one tracing is superimposed on the other The roentgenographic studies are facilitated by sedating the younger children

This survey does not represent a research project to prove a certain thesis The objective is to report the ear pathology and audiological findings in 401 individuals with cleft lips and palates observed in a period of eight years, furthermore, the study was not strictly limited to observations of diseases of the ear, nose and throat According to the concept of *total patient care*, and in order to stimulate interprofessional understanding of the defect, the ear pathology was related to the genetic heritage, metabolic climate, growth and development pattern, and to the surgical and non-surgical modalities of rehabilitation

ANOMALIES OF THE EAR IN CLEFT PALATE PATIENTS

The association of cleft palate and other physical malformations, particularly due to arrested development, has been frequently observed, however, as far as the congenital anomalies of the ear are concerned, very few cases have been reported, and no impression of its average incidence of occurrence has been given

Fogh-Andersen[18] in a study of 1013 patients with cleft lip or cleft palate reported severe malformations in more than ten per cent, with three or more rare abnormalities present in a great number of infants He observed also a patient with cleft lip and palate associated with cranioschisis and atresia of the auricles, a child with cleft palate, atresia of the auricles and syndactilism, and a case of cleft lip with malformation of the auricles Ivy[10] reported about 11 per cent of other congenital anomalies in the cleft lip or cleft palate patients observed in Pennsylvania

Among the 401 patients processed through this study, 62 (15 per cent) exhibited other congenital anomalies (Scheme I) The number of instances of mandibular micrognathia and upper and lower limb malformations is considerable Twelve of the patients presented the syndrome of Pierre

Robin (hypoplasia of mandible, cleft palate, glossoptosis, respiratory difficulty and malnutrition)

The patients with mandibular micrognathia and the majority of the other malformations presented a cleft of the hard and soft palates (53 per cent of 62 cases) Fogh-Andersen[18] divided his cases into "hereditary" and "solitary," according to a hereditary link that could be substantiated In his analysis he also pointed out that the majority of patients with lip involvement are supposed to be hereditary, while "in the isolated palatal cleft there is a considerable admixture of non-hereditary cases" In our series, although numerically not so large, it was observed that only exceptionally were

SCHEME I

CONGENITAL ANOMALIES IN CLEFT PALATE PATIENTS

	Anomaly	Cases	Types
1	*Anomalies of the Head*	2	*Acrocephaly, microcephaly*
2	Asymmetry of the Face	3	
3	Anomalies of the Eye	6	Corneal opacity, microphtalmia, iris colobomata, retrolental fibroplasia, optic atrophy, ptosis of eye-lids, atresia of naso lacrimal duct, strabism
4	Anomalies of the Ear ..	8	See Scheme II
5	Choanal Atresia ..	1	
6	Mandibular Micrognathia	16	Pierre Robin's syndrome was seen in 12 of these cases
7	Tracheal Stenosis	1	
8	Anomalies of the Neck	3	Klippel Feil syndrome, branchial cyst
9	Anomalies of the Heart	4	Absence of interventricular septum, patent ductus arteriosus
10	Anomalies of the Rectum ..	1	
11	Anomalies of Genitalia	5	Hydrocele cryptorchidism, phymosis
12	Anomalies of Upper Limb	9	Adactilism, syndactilism, webbed fingers, ankylosis of interphalangeal joints, club hands
13	Anomalies of Lower Limb	13	Adactilism, syndactilism webbed toes, club feet, metatarsus varus calcaneous valgus, absence of left foot
14	Hemangiomas	4	Observed on the tongue, chest back and buttock
15	Mongolism	3	

other anomalies associated with cleft palate cases in which a hereditary relationship could be demonstrated. This corresponded to Fogh-Andersen's observations.

Anomalies of the ear were noted in eight of the cleft palate patients, or 2 per cent of all the cases, or 13 per cent of the associated anomalies. Mild anomalies, such as pointed ear, lop ear, Darwin's tubercle were not included. The degree of involvement in the cases ranged from a moderate malformation of the auricle, atresia of the external auditory canals, to the more severe configurations of microtia, melotus, asymmetry of face, or peripheral facial paralysis (Scheme II).

SCHEME II

ANOMALIES OF THE EAR IN CLEFT PALATE PATIENTS

	Anomalies of the Ear	Associated Anomalies
1	Deformity of the Auricles	Cleft of the hard and soft palates Klippel Feil syndrome anomalies of the heart and rectum
2	Deformity of the auricles and stenosis of external auditory canals	Cleft of the hard and soft palates, mandibular micrognathia
3	Deformity of the auricles and displacement of the right external auditory canal	Cleft of the hard and soft palates mandibular micrognathia with Pierre Robin syndrome
4	Microtia and stenosis of external auditory canal right	Unilateral cleft of the lip and palate right
5	Microtia displacement and stenosis of external auditory canal right	Unilateral cleft of the lip and palate left asymmetry of the face right anomaly of the heart
6	Microtia and atresia of external auditory canal right with stenosis of external auditory canal, left	Cleft of the soft palate
7	Microtia displacement and atresia of external auditory canal right with stenosis of external auditory canal left	Cleft of the soft palate asymmetry of the face right peripheral facial paralysis right.
8	Atresia of external auditory canals	Bilateral cleft of the lip and palate optic atrophy

It is of interest that three cases were associated with clefts of the hard and soft palates and two with clefts of the velum. The problem of the pathogenic relationship between cleft palate and anomalies of the ear deserves more consideration

Development

Independent of the exact mechanism of development of cleft lip and palate, the importance of the mandibular arch is fully recognized According to the classical theory of fusion of nasal and maxillary processes, or the theory of mesodermal penetration, it seems that an arrest of development is significant in the pathogenesis of clefts of the lip and palate In particular, the theory of non-fusion of the palatine processes is for most investigators still valuable to account for the origin of the clefts of the hard and soft palates On the other hand, it is known that the external auditory canal develops from the first branchial groove and the auricle from the adjacent mandibular and hyoid arches The Eustachian tube and tympanic cavity develop from the first pharyngeal pouch, while the malleus and incus are formed from Meckel's cartilage, and the stapes from Reichert's cartilage

Among the cases with cleft palate, two patients are observed with unilateral microtia and homolateral asymmetry of the face (due to under development of the hemimandible), and two patients with bilateral deformity of the auricles and mandibular micrognathia This association of mandibular, palatal and auricular anomalies seems to indicate an arrest of development involving primarily the first branchial arch In fact, there is a definite parallelism between the formation of the mandible and the development of the auricle in its movement craniodorsally from its original caudo-ventral position

✓ Canick[20] has recently analyzed the embryology, pathologic anatomy, and etiology of cleft lip and palate He concluded that the mechanism of embryogenesis is complex and that several factors, both inherent and environmental, influence the development of multiple anomalies Genetic factors, dominant, recessive, incompletely sex-linked, and of reduced penetrance, have been considered Environmental factors, such as vitamin and nutrient deficiencies, maternal diseases and age seem to play a part in teratogenesis Duration, intensity and time of action of any agent seems to be of greater importance than the type of agent

✓ In the case of palatal and auricular anomalies, the normal development of the first branchial arch remains incomplete or deviates Hereditary factors and environmental agents may be the cause of this altered development, however, the observation that "solitary" cases of cleft palate and lip are more frequently associated with other anomalies, the greater incidence of association of anomalies in clefts of the hard and soft palates, the pathogenesis of which has often been related to micrognathia and nasal displacement of the tongue, the statistical data of no definite increase of other anomalies in relatives of cleft palate patients indicates the possibility of exogenous causes interfering with the early embryonic development It is possible that induced mutations determine a disturbance of growth with the consequent occurrence of multiple anomalies due to arrest of development

EAR PATHOLOGY AND HEARING DISTURBANCES IN CLEFT PALATE PATIENTS

Several factors were seen to be clearly related to the pathogenesis of ear disease in cleft palate patients

In Scheme III, the cleft palate patients are classified according to six groups, five of which are typical The atypical group includes four cases of bilateral cleft lip and unilateral cleft palate, seven cases of unilateral cleft lip and bilateral cleft palate, two cases of unilateral cleft lip and cleft velum, one case of median cleft lip, bilateral alveolar ridge and cleft velum, four cases of unilateral cleft lip and submucous cleft palate and four cases of unilateral cleft hard and soft palate

There is a male preponderance in the types of clefts involving the lip and a female preponderance in those involving only the hard and soft palates The group of submucous cleft palate is too limited for any sex distribution In the unilateral cleft lip and palate there is a definite prevalence on the left side

The number of cases with ear pathology, unilateral or bilateral, totaled 184, or 45 8 per cent Of these cases, 16 8 per cent were unilateral and 83 2 per cent bilateral The *distribution of ear disease as to sex strictly corresponded to*

SCHEME III

INCIDENCE OF EAR PATHOLOGY AND HEARING DISTURBANCES IN CLEFT PALATE PATIENTS

Type of Cleft	Cases	Male	Female	Total	Cases with Ear Pathology Uni	Bilateral	Male	Female	Cases with Uni and Bilateral Hear Loss
1 Bilateral Cleft Lip and Palate ..	65	48	17	33 (50%)	6	27	25	8	32
2 Unilateral Cleft Lip and Palate	133 Rt. 48 Lt 85	83	50	62 (46%) Rt 24 Lt 38	15	47	37	25	54
3 Cleft Hard and Soft Palates	106	48	58	33 (31%)	5	28	15	18	30
4 Cleft of the Soft Palate	45	20	25	25 (55%)	2	23	13	12	20
5 Submucous Cleft Palate	30	16	14	22 (73%)	3	19	9	13	19
6 Atypical Cases .. ----	22	15	7	9 (40%)	—	9	6	3	3
Total .. --- ..	401	230	171	184	31	153	105	79	158
Percentage --- ---		57 4%	42 6%	45 8%	16 8%	83 2%	57 2%	42 8%	39 4%

SCHEME IV

TYPE OF EAR PATHOLOGY AND HEARING LOSS IN CLEFT PALATE PATIENTS

Type of Cleft	Pathol Ears	Cong Anom	Rad Mast	Perf	Scar	Retr	Alt of Lust	Pathol Ears Tested	Normal Hearing	Mild Hear Loss	Mod Hear Loss	Sev Hear Loss
1 Bil Cleft Lip and Palate	60	2	1	18	21	12	6	56	7	36	13	—
2 Unil Cleft Lip and Palate	109	2	2	27	23	34	21	88	6	57	22	3
3 Cleft Hard and Soft Palate	61	3	1	22	12	19	4	52	2	27	21	2
4 Cleft Soft Palate	48	2	1	12	10	12	9	38	3	20	14	1
5 Submucous Cleft Palate	41	—	1	9	14	11	6	38	4	20	9	5
6 Atypical Cases	18	—	—	5	—	8	5	16	10	2	3	1
Total	337	9	6	93	80	96	51	288	32	162	82	12
Percentage ..		2 7%	1 8%	27 6%	23 4%	28 4%	16 1%		11 1%	56 2%	28 1%	4 3%

that of the cleft palate patients The total number of cases with definite hearing loss is 158, or 39 4 per cent

In Scheme IV a more detailed analysis of the type of ear pathology and hearing loss is noted Ear pathology is classified according to congenital anomalies, surgical procedures and severity of infection The latter is divided according to the presence of dry or discharging perforations (evidence of previous or present purulent otitis media), scarring (evidence of repaired suppurative otitis media), retractions (evidence of repeated severe catarrhal otitis media), and alterations of luster (evidence of mild catarrhal otitis media) Each ear is reported only once relative to the greatest degree of pathology

Perforations were noted in 27 6 per cent, scarring in 23 4 per cent, retraction in 28 4 per cent, alteration of luster in 16 1 per cent of the cases It seems, therefore, that there is no significant preponderance of catarrhal or purulent otitis media in cleft palate patients Central perforations prevailed as far as the site is concerned

Not all of the cases with ear pathology could be tested audiometrically because of age, mental retardation or uncooperativeness In some the audiogram was not reliable Among 288 pathologic ears accurately tested, 11 1 per cent did not show any hearing loss, 56 2 per cent showed a mild hearing loss (less than 30 db), 28 4 per cent showed a moderate hearing loss (between 30 and 60 db), and 4 3 per cent showed a severe hearing loss (over 60 db)

Perceptive loss of hearing was noted in five cases, all others were of the conductive type In one case a severe unilateral perceptive hearing loss and a moderate mixed type of hearing loss in the opposite ear was observed in a patient who had mumps previously In a brain injury child, the audiogram revealed a bilateral moderate hearing loss without any ear pathology The same finding was noted in a deaf child due to previous meningitis, the vestibular test failed to reveal any response In one case unilateral complete deafness, due to previous labyrinthitis secondary to middle ear disease was noted, no response was elicited to the vestibular test In an-

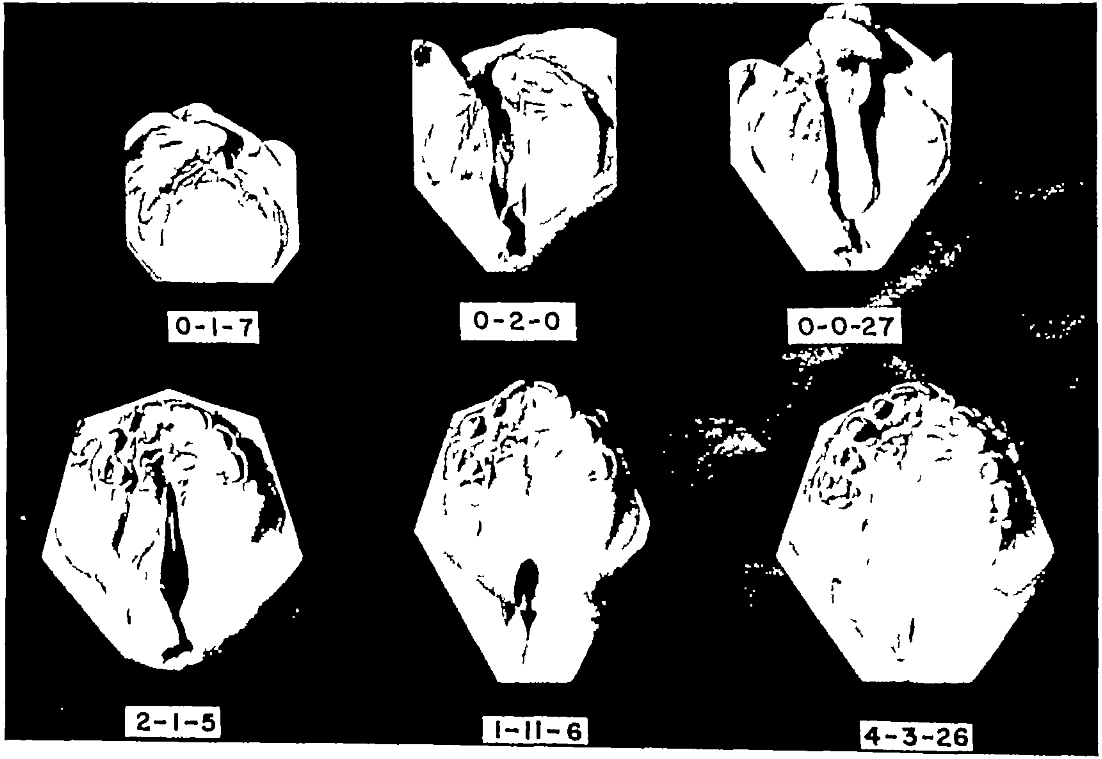

Fig 2 Plaster cast reproductions of several varieties of unoperated clefts of the lip and palate

other child a unilateral severe perceptive type of hearing loss was noticed, but no etiologic basis could be evinced

The majority of cases revealed a conductive type of hearing loss with predominant loss in the low frequencies and usually bilateral with a similar pattern in both ears A close relationship was noted between the degree of middle ear disease and degree of hearing loss The severest cases of hearing loss were either perceptive or due to surgical procedures of the mastoid Since conductive hearing loss, if not curable, is at least partially preventable, the role of the otologist in the follow-up of cleft palate patients is paramount

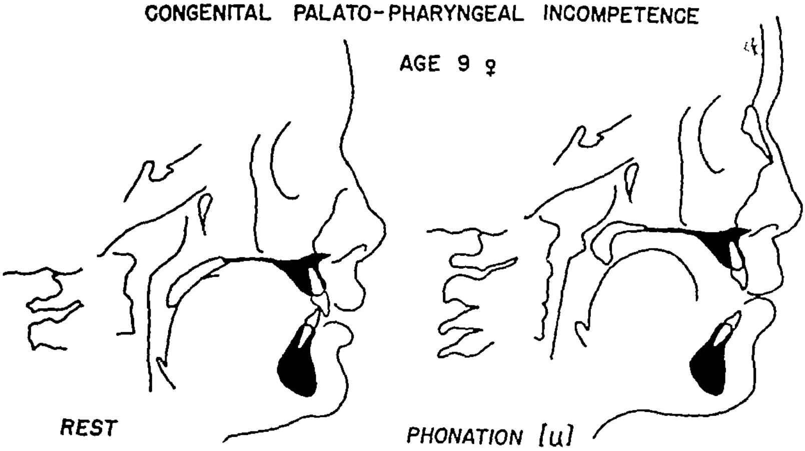

Fig 3 Palatopharyngeal incompetence as evidenced by cephalometric roentgenographic analysis from lateral films obtained at rest and during phonation of the vowel u as in boom Note congenital shortening of the palate and inability of the velum to make contact with the posterior pharyngeal wall The formation of Passavant's bar on the posterior wall of the pharynx is indicated in the stippled area.

INCIDENCE OF EAR PATHOLOGY ACCORDING TO AGE GROUP

In subdividing the cases according to their age, expressed in years, it was apparent that the incidence of middle ear pathology followed a different pattern according to four groups which appeared strikingly uniform in their structure Diagram I is very demonstrative

In the group of cases below one year of age only 6 per cent were found to have middle ear pathology A definite increase to 27 per cent of ear disease was noticed in the group of pre-school children (between one and four years of age) A more amazing increase of ear disease was observed in the school children (between five and 13 years of age) subdividing the latter group into two (five to eight years and nine to 13 years) the incidence did not change substantially In the limited number of cases over 13 years of age, the frequency of ear disease did not vary significantly It seems, therefore, that a gradual increase of ear disease exists up to the school age and then persists at a plateau level

In analyzing the cases that were followed over a long period of time there was a comparable increase of ear pathology in passing from the pre-school age to the school age The contagious diseases, as well as the increased incidence of upper respiratory infections, are factors that tend to raise the percentage of ear pathology and hearing loss in a patient with previously altered anatomic and physiologic relationships, as exists in a child with a cleft of the palate, a repaired cleft or a cleft fitted with a prosthesis

Beatty[21] reported that in his experience the majority of "well fed and well cared for" infants do not develop ear infection prior to the age for surgical closure of the palate

The frequency of ear disease in school age children observed in this study is most significant and expresses in figures the higher incidence of ear pathology in cleft palate patients compared to the normal child The values obtained in the School Surveys of the Hearing Conservation Program, which throughout the country average between 8 and 10 per cent, are used as controls Values of 60 per cent of hearing impairment in cleft palate children in school age measure this difference beyond discussion, as evidenced in the charts (Scheme III and Diagram I)

INCIDENCE OF EAR PATHOLOGY ACCORDING TO TYPE OF CLEFT

An analysis of Scheme I reveals that a different incidence of ear pathology exists for each type of cleft (see Fig 2) Maximum frequency prevails for submucous cleft palate (73 per cent) and a minimum for clefts of the hard and soft palates (31 per cent), however, as was mentioned in the preceding paragraph, a definite difference of incidence, according to the age group, was seen and it is obvious that no comparison can be made between different types of clefts without considering the age factor

In Scheme V the incidence of ear pathology in cleft palate patients according to the type of cleft in the pre-school and school age is noted The atypical cases are not considered, because the structure is not uniform

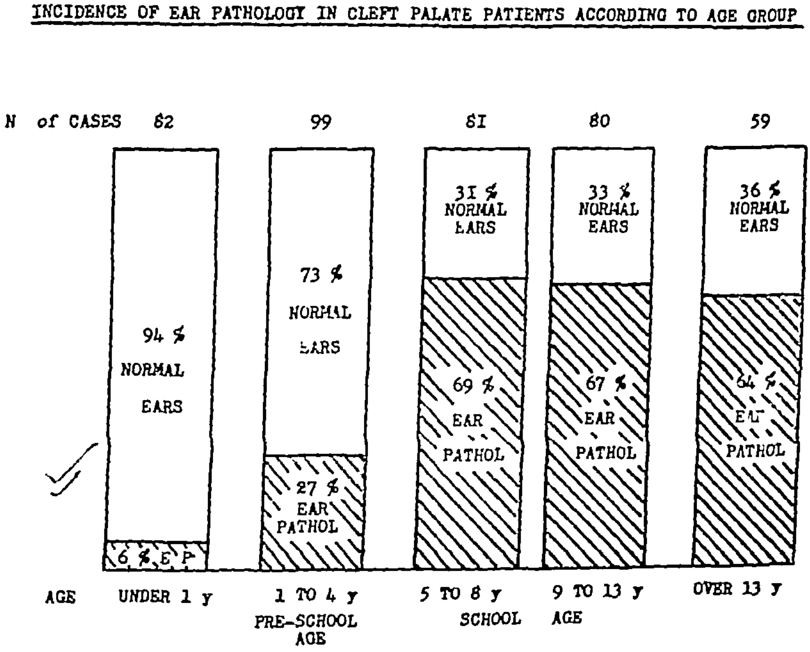

DIAGRAM I

It is quite significant that in the school age group the incidence of ear pathology, notwithstanding the small number of cases, is relatively uniform for each type of cleft The average value being 68 per cent, variations exist between 62 per cent for clefts of the hard and soft palates and bilateral clefts of the lip and palate and 74 per cent for clefts of the soft palate

The figures reported in the pre-school age group are too small to deserve consideration, however, one is justified in emphasizing the small incidence of ear pathology in this group for the clefts of the hard and soft palates (12 per cent of 33 cases) The reason for this relatively small frequency of ear pathology is not clear This is probably related to a less distorted anatomical configuration of the head spaces and relatively greater intactness of the neuro-muscular mechanism of the Eustachian tube

SCHEME V

INCIDENCE OF EAR PATHOLOGY IN CLEFT PALATE PATIENTS ACCORDING TO TYPE OF CLEFT

Type of Cleft	Pre-School Age (From 1 to 4) Total Number of Cases 91		School Age (From 5 to 13) Total Number of Cases 156	
	Cases with Ear Pathology	Cases with Normal Ears	Cases with Ear Pathology	Cases with Normal Ears
Average Values	27 %	73 %	68 %	32 %
1. Bilateral Cleft Lip and Palate	2 (25%)	6 (75%)	16 (62%)	10 (38%)
2. Unilateral Cleft Lip and Palate	11 (30%)	27 (70%)	35 (71%)	14 (29%)
3. Cleft Hard and Soft Palates	4 (12%)	29 (88%)	24 (62%)	15 (38%)
4. Cleft of the Soft Palate	6 (55%)	5 (45%)	14 (74%)	5 (26%)
5. Submucous Cleft Palate	—	1	17 (73%)	6 (27%)

Among the 62 cases of unilateral cleft lip and palate, 21 (33 per cent) showed unilateral or definitely more pathology in the ear opposite the side of the cleft, seven on the same side and the remaining, uniform, bilateral pathology Of the 21 cases with greater contralateral pathology, six were untreated and 15 were postoperative. No definite relationship was noted in these cases with unilateral nasal obstruction

RELATIONSHIP OF EAR PATHOLOGY TO WIDTH OF THE CLEFT

According to Nassy,[16] the frequency of middle ear disorders in cleft palate patients depends on the size of the cleft This

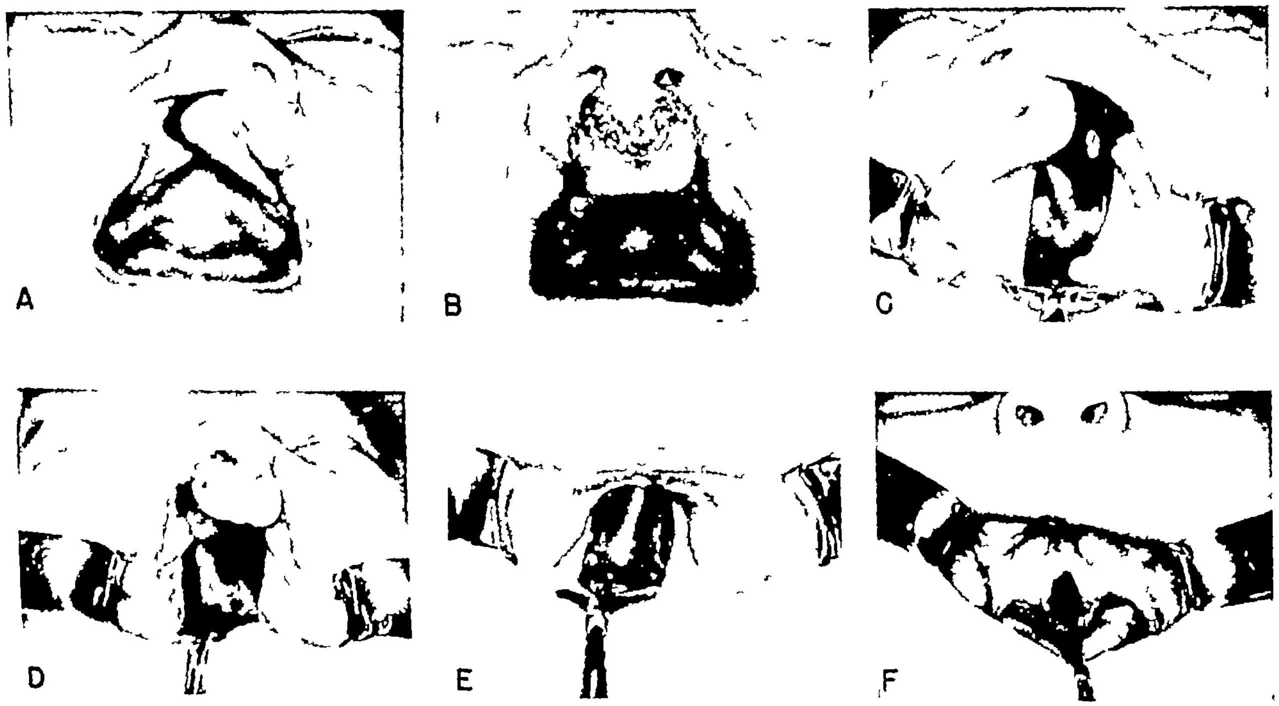

Fig 4 Varieties of clefts of the hard and soft palates A.—Unilateral cleft of the alveolar process with intact hard and soft palates B—Incomplete bilateral cleft of the lip with intact hard and soft palates C—Complete unilateral cleft of the lip hard and soft palates D—Complete bilateral cleft of the lip hard and soft palates E—Cleft of the hard and soft palates without involvement of the lip or alveolar process F—Cleft limited to the soft palate

was not observed in an analysis of a group of school children with cleft palates in this study

As the concept of width is purely subjective and variable with the *dimensions of time, the closure of lip and orthodontic* treatment, it is necessary to analyze children of a certain age group and with untreated palates Borderline cases between "wide" and "narrow" were not considered The different types of clefts are considered together as was demonstrated in the preceding paragraph In the school age group the difference in frequency of ear pathology between the different types of clefts is insignificant

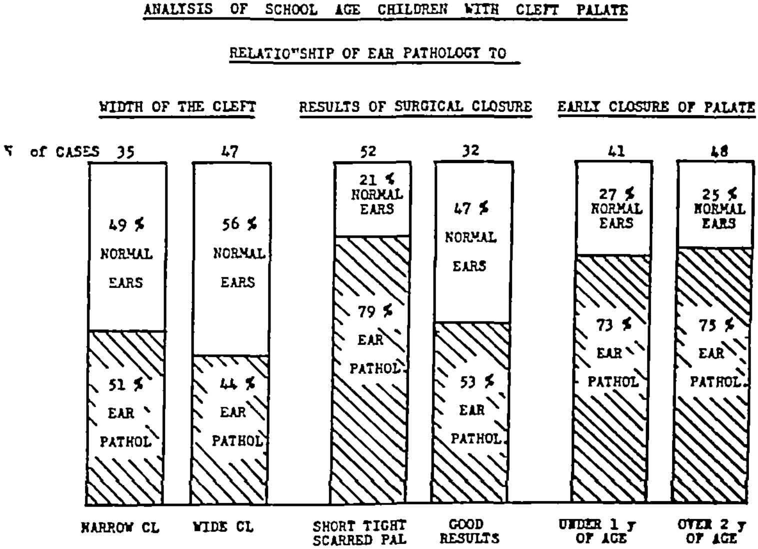

DIAGRAM II

Among 47 definitely wide clefts (not amenable to surgical closure, see Fig 4) 21 (44 per cent) showed ear pathology and 26 (56 per cent) normal ears (see Diagram II) In the same age group among 35 narrow clefts (immediately prior to surgical closure) 18 (50 per cent) showed ear pathology, and 17 (49 per cent) normal ears, therefore, it does not seem that the width of the cleft has a definite relationship to the frequency of middle ear disorders in cleft palate patients in the school age

RELATIONSHIP OF EAR PATHOLOGY TO SURGICAL REPAIR OF CLEFT PALATE

In Diagram III the relationship of surgical or prosthetical closure of cleft palate in pre-school and school children for the most important four typical clefts is evaluated

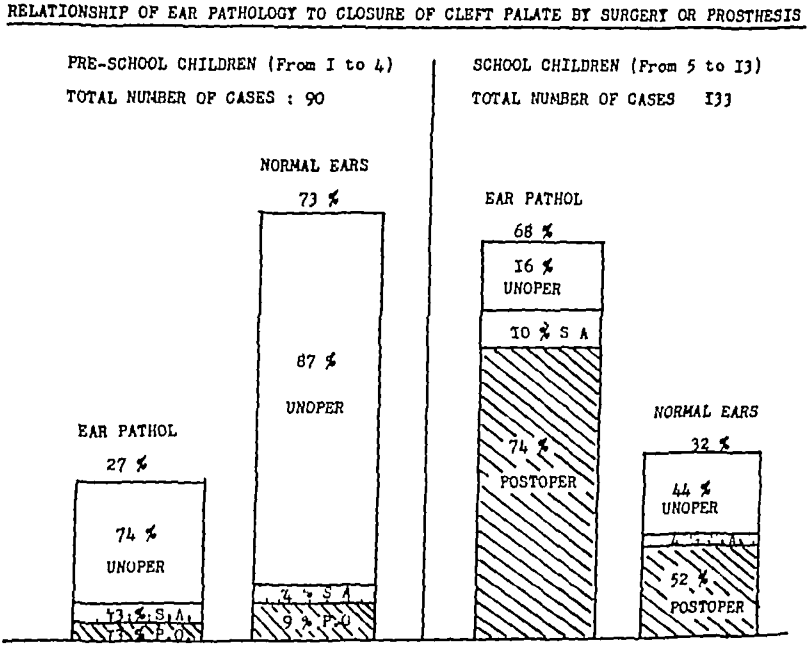

DIAGRAM III

Both in the pre-school and school age groups there is a higher percentage of postoperative cases in the pathologic group than in the normal, however, the most significant finding is the definite increase of ear pathology in passing from the pre-school age to the school age group parallel to the increased number of postoperative cases In the school age children with *surgically closed palates*, approximately 74 per cent had ear pathology (see Diagram III)

As other factors are involved in the difference of frequency of ear disease in the two age groups, further analysis of the importance of surgical closure in relation to ear pathology is made. Among the cases followed over a period of time, 16 developed otitis media in the school age after surgical repair and two after being fitted with a speech aid. Only six other untreated cases developed otitis media in the school age group. An analysis of the results of surgical repair among 52 cases in the school age with a palate that was short, tight and scarred, 41 (79 per cent) showed ear disease, and 11 (21 per cent) had normal ears. Among the 32 cases in the school age group with a good surgical repair, 17 (53 per cent) showed ear pathology, and 15 (47 per cent) had normal ears (see Diagram III). Twelve of the school age cases had more than five palatal operations: 8 (66 per cent) of them had ear pathology and 4 (34 per cent) showed normal ears.

The influence of early surgical closure was also considered. 41 of the cases of school age had palatal closure before one year of age, 30 (73 per cent) had ear pathology, and 11 (27 per cent) had normal ears. The percentage of ear pathology in children with a cleft palate closed after two years of age (when, according to Subtelny,[22] a leveling off of the dimensions of the cleft, maxillary and nasopharyngeal development has been reached) was approximately the same—over 48 cases, 36 (75 per cent) had ear pathology and 12 (25 per cent) had normal ears (see Diagram III).

Surgical closure of the palate appears to be an extremely important factor in the pathogenesis of middle ear disorders. The mechanism seems to be related to a process of atrophy, scarring and sclerosis of tubal muscles after surgery. The higher incidence of ear pathology in the cases with a scarred, tight palate compared with the good operative results accounts for this interpretation.

It has been said that simple anatomical closure of a palate without the formation of a velopharyngeal sphincter makes surgical treatment unsatisfactory. Certainly, the inadequacy of tubal musculature after surgery should be considered in the evaluation of a surgical repair of the palate; furthermore, the opinion that early closure of the palate avoids secondary atrophy of palatal muscles and prevents otitis media, is not supported by this study The dangers of early closure in relation to interference with centers of bone growth, and consequent serious disturbances of development of the bones of the jaw and face, and the high incidence of middle ear pathology, factors which are probably directly or indirectly related to each other, questions the validity of surgery at an early age, in many cases

RELATIONSHIP OF EAR PATHOLOGY TO CLEFT PALATE PROSTHESIS

Several otolaryngologists have the conviction that there is a relationship of cleft palate prosthesis with upper respiratory health and audition No definite statement on the association of ear pathology to cleft palate prosthesis has ever been made

Twenty-four of the cases in this study that were fitted with a speech aid were observed Twenty of them were unoperated and four postoperative The four postoperative and 13 of the unoperated cases showed ear pathology

Clinical experience reveals a frequent association of inflammatory changes of the upper airways, lymphoid hyperplasia and middle ear pathology with cleft palate prosthesis In most of these cases, however, an ill-fitting appliance or poor hygiene of the speech aid was noted It is known that the size and shape of the segments of the appliance are highly individualistic The contour of the palatal extension must conform strictly to the natural contour of the velar tags, and the bulb must adapt to the proportions of the patient's nasopharyngeal port The level at which the bulb is placed in the nasopharynx is of utmost importance The bulb must be reduced in size with the development of the patient's muscles It must be pointed out that when a prosthesis is defective or the hygiene of the appliance is unsatisfactory, there is a disturbance of the physiology of the nose and nasopharynx with consequent dysfunction of the Eustachian tube

RELATIONSHIP OF EAR PATHOLOGY TO NASAL DISTURBANCES IN CLEFT PALATE PATIENTS

That nasal physiology in cleft palate patients is severely disturbed, is quite apparent The malformations of the alar cartilages with stenosis of the nares, the septal deflections with obstruction of the airway, and the abnormal communication of oral and nasal cavities are the main causes of this disturbance The inspiratory and expiratory air currents, the air pressures, the humidifying, heating and purifying action of cilia and mucous blanket, the pH and bacteriology, must surely be modified in cleft palate patients as compared with the normal As a consequence of altered physiology these children are more prone to frequent upper respiratory infections and vasomotor changes

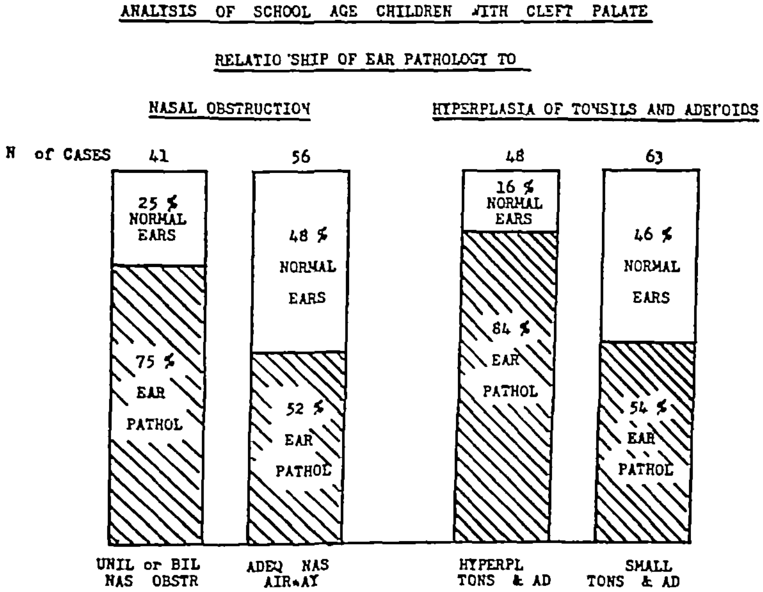

DIAGRAM IX

In an analysis of ear pathology related to nasal disturbances, a group of 41 school-age children with complete unilateral or bilateral obstruction of the nasal airway on an anatomical, catarrhal or vasomotor basis were studied Thirty-one of them (75 per cent) showed ear pathology, while the opinion that early closure of the palate avoids secondary atrophy of palatal muscles and prevents otitis media, is not supported by this study The dangers of early closure in relation to interference with centers of bone growth, and consequent serious disturbances of development of the bones of the jaw and face, and the high incidence of middle ear pathology, factors which are probably directly or indirectly related to each other, questions the validity of surgery at an early age, in many cases

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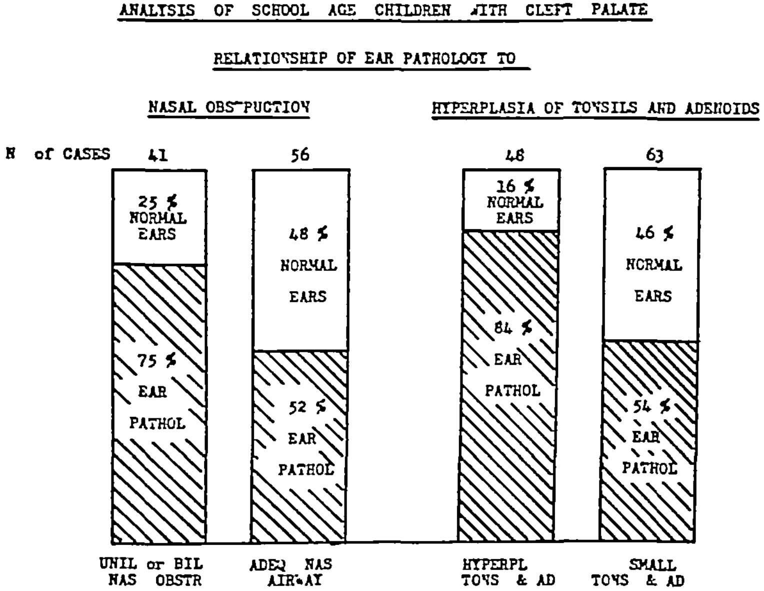

DIAGRAM IV

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RELATIONSHIP OF EAR PATHOLOGY TO HYPERPLASIA OF TONSILS AND ADENOIDS IN CLEFT PALATE PATIENTS

The importance of adenoid growth and enlarged tonsils in the etiology of catarrhal and purulent otitis media in children has been stressed On the other hand the significance of tonsils and adenoids for an adequate velopharyngeal closure in cleft palate patients is paramount Inflammatory changes of lymphoid tissue in these patients should receive immediate conservative treatment and be controlled as promptly as possible

In a group of 48 school-age children with hyperplasia of tonsils and adenoids, 40 (84 per cent showed ear pathology and eight (16 per cent) had normal ears A control group of 63 school children with operated or unoperated clefts and with small tonsils and scanty amount of adenoid tissue, showed 34 cases (54 per cent) with ear pathology and 29 (46 per cent) with normal ears (see Diagram IV)

RELATIONSHIP OF EAR PATHOLOGY TO GENERAL FACTORS IN CLEFT PALATE PATIENTS

Prematurity, malnutrition, dehydration, improper feeding methods and acute exanthemata appeared to be important factors in the development of severe purulent otitis media in cleft palate children On the contrary, no definite relationship could be found between the incidence of ear pathology and multiple congenital anomalies

DISCUSSION

In an analysis of 401 patients with various types of clefts of the palate, it has been observed that a multiplicity of factors are responsible for the large percentage of patients with middle ear disorders and hearing disturbances

Apart from congenital anomalies and a few general factors, such as genetic predisposition to ear pathology, resistance to infection and nutritional status, it is apparent that Eustachian tube dysfunction, primary or secondary to nasal and nasopharyngeal pathology, or surgical and non-surgical means of cleft palate closure, is the pathogenic basis of the greater majority of ear disorders in cleft palate patients than in normals

A considerable emphasis has been placed on the fact that the inactivation of the velopharyngeal closure in the open cleft palate allows the food to enter the nasopharynx, and that atypical tongue habits cause continuous irritation and bathe the Eustachian tube openings with irritants

The disturbed physiology and hygiene of the air spaces of the head is surely a factor in the pathogenesis of otitis media in cleft palate children It is noteworthy how a relatively small percentage of these children under one year of age suffer from ear pathology Lysozime and inhibitory activity of saliva and nasal secretions on bacterial growth must play an important role in these children who are free from infection, as well as the absence of environmental contact

In no cases was any fluctuation noted of the tympanic membrane during respiration, as one would expect in a persistent patent Eustachian tube, rather, the kind of pathology that is described (alteration of luster, retractions and scarring) and the improvement obtained by inflation indicate that the physiopathology of the Eustachian tube in cleft palate patients is based on a persistent closure of the orifice

It is of extreme importance to analyze the anatomy and physiology of a normal velum in order to understand the physiopathology of a cleft palate in relation to the function of the Eustachian tube (see Figs 5 to 8)

The soft palate is a muscular hinge which is attached anteriorly at the posterior border of the hard palate by means of an aponeurotic structure and moves freely posteriorly The muscles enter from the sides and interlace in the midline, 10 (25 per cent) had normal ears In a control group of 56 school children with an adequate bilateral nasal airway, 29 (52 per cent) had ear disorders and 27 (48 per cent) had normal ears (see Diagram IV)

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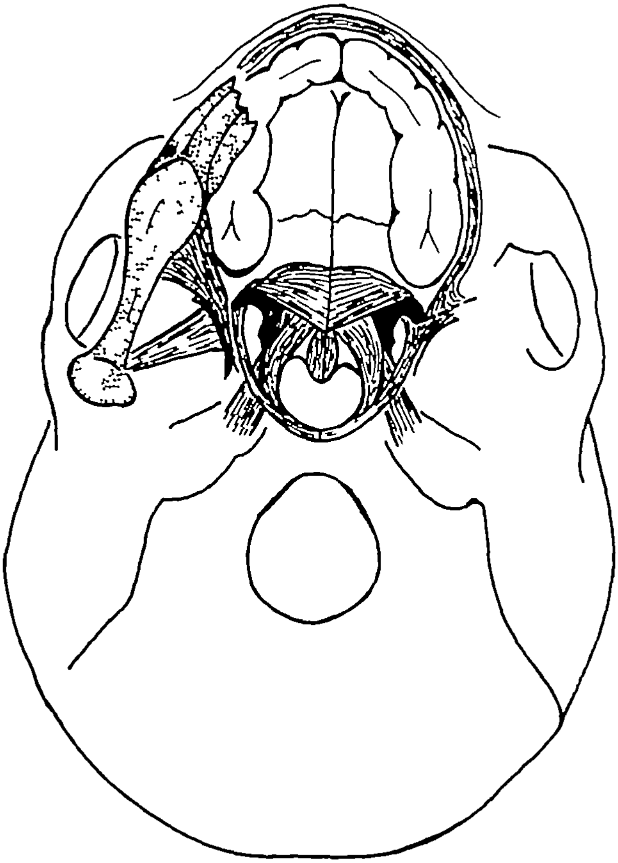

Fig 5 Drawing of the inferior view of a skull illustrating the harmonious balance of intact musculature Completeness of the musculature of the soft palate restrains the outward pull of the pterygoid muscles

each pair forming a sling arching either upward or downward The musculus uvulae fastens longitudinally all of these muscles in the midline without forming a real raphe

Three pairs of muscles arch upward the levator palati, the tensor palati and the pterygopharyngeus of the superior constrictor muscle of the pharynx The levator veli palatini arises from the apex of the petrous bone and from the medial lamina of the cartilage of the auditory tube, enters the velum with its fibers spreading downward and medialward, and blending with those of the opposite side The tensor veli palatini arises from the scaphoid fossa and the spina angularis of the sphenoid and from the lateral wall of the cartilage of

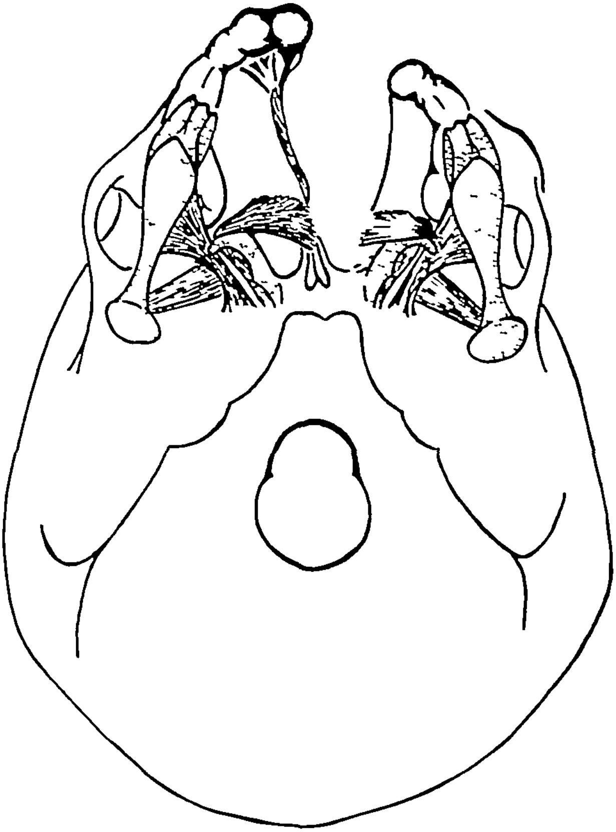

Fig 6 Drawing of the inferior view of a skull to illustrate the loss of continuity of muscle structure as a result of a congenital cleft. There is decreased restraint on the outward pull of the pterygoid musculature

the auditory tube, its tendon, after winding around the pterygoid hamulus, is inserted into the palatine aponeurosis and the posterior border of the palatine bone The pterygopharyngeus muscle arises from the pharyngeal raphe approximately 1 5 centimeters below the pharyngeal tubercle of the occipital bone It runs outward toward the pterygoid plate of the sphenoid bone, one part being inserted on it, and the hamular process and the remaining fibers running medially to be inserted into the palatal aponeurosis

Two pairs of muscles arch downward the glossopalatinus in front forms the anterior pillars and the pharyngopalatinus behind forms the posterior pillars The glossopalatinus arises from the anterior surface of the soft palate, where it is continuous with the muscle of the opposite side and is inserted into the side of the tongue The pharyngopalatinus arises from the soft palate and divides into two fasciculi The an-

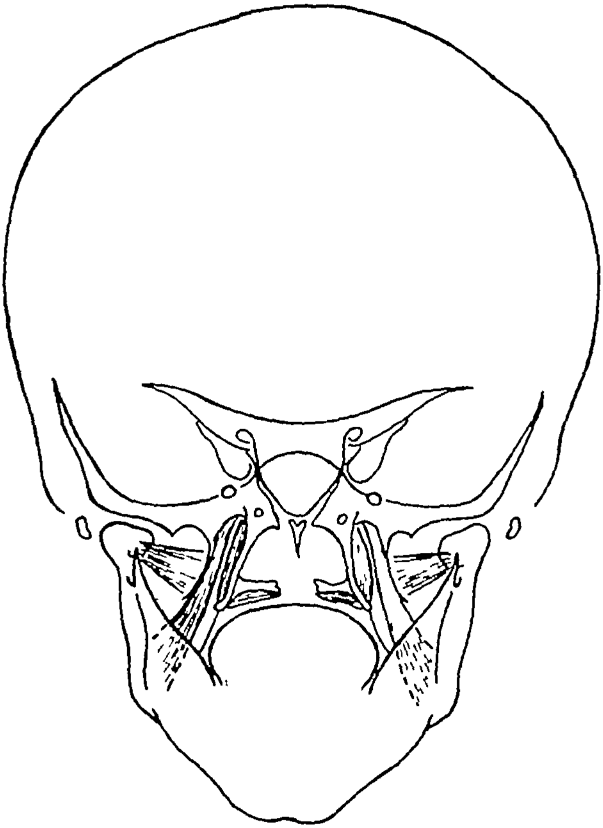

Fig 7 Frontal view of the nasopharyngeal area illustrating a loss of continuity of the tensor veli palatini muscles as a result of the cleft the outward pull of the internal and external pterygoid muscles the patent embryonic suture on both sides of the body of the sphenoid the tongue *represented by the stippled area the pterygo mandibular raphe extending* downward on both sides of the tongue

terior fasciculus is inserted into the posterior border of the thyroid cartilage and into the lateral and posterior wall of the pharynx The posterior fasciculus joins the opposite muscle in the midline An important muscular bundle connected with the latter fasciculus is the salpingopharyngeus muscle, which forms the salpingopharyngeal fold It arises from the inferior part of the auditory tube and blends with the posterior fasciculus of the pharyngopalatinus

Podvinec,[23] in a recent study of the physiology and pathology of the soft palate, maintained that as the individuality of the different muscles becomes lost in the velum, it is reasonable to conclude that they are functioning together He analyzes the functions of the soft palate as follows *a*, to facilitate the transport of the bolus from the oral cavity to the pharynx, *b* to close the nasopharyngeal port in swallowing and speech articulation, *c* to elevate the larynx in swallowing and speech, *d* to open the Eustachian tube during deglutition and yawning

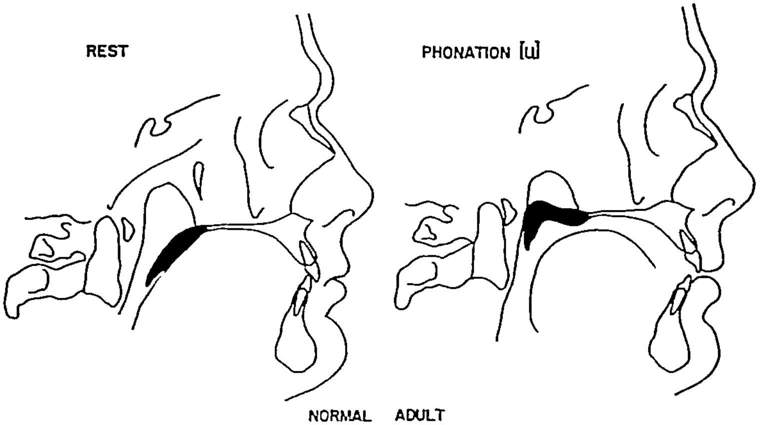

Fig 8 Palatopharyngeal valving in a normal adult Tracings of lateral cephalometric roentgenograms reveal the position of the soft palate within the nasopharynx At rest the soft palate outlined in black rests on the dorsum of the tongue During the sustained phonation of the vowel u the soft palate elevates to contact the posterior wall of the nasal pharynx.

The relationship between movements of the soft palate and opening of the Eustachian tube deserves more consideration Perlman[24] in an authoritative study, reviewed the literature and analyzed with personal observations the movements and the nature of the physiological opening of the Eustachian tube In phonation, the posterior lip of the torus tubarius is lifted passively during the elevation of the soft palate and floor of the tube by the levator palati, while the simultaneously rising salpingopharyngeus contributes actively to an addi-

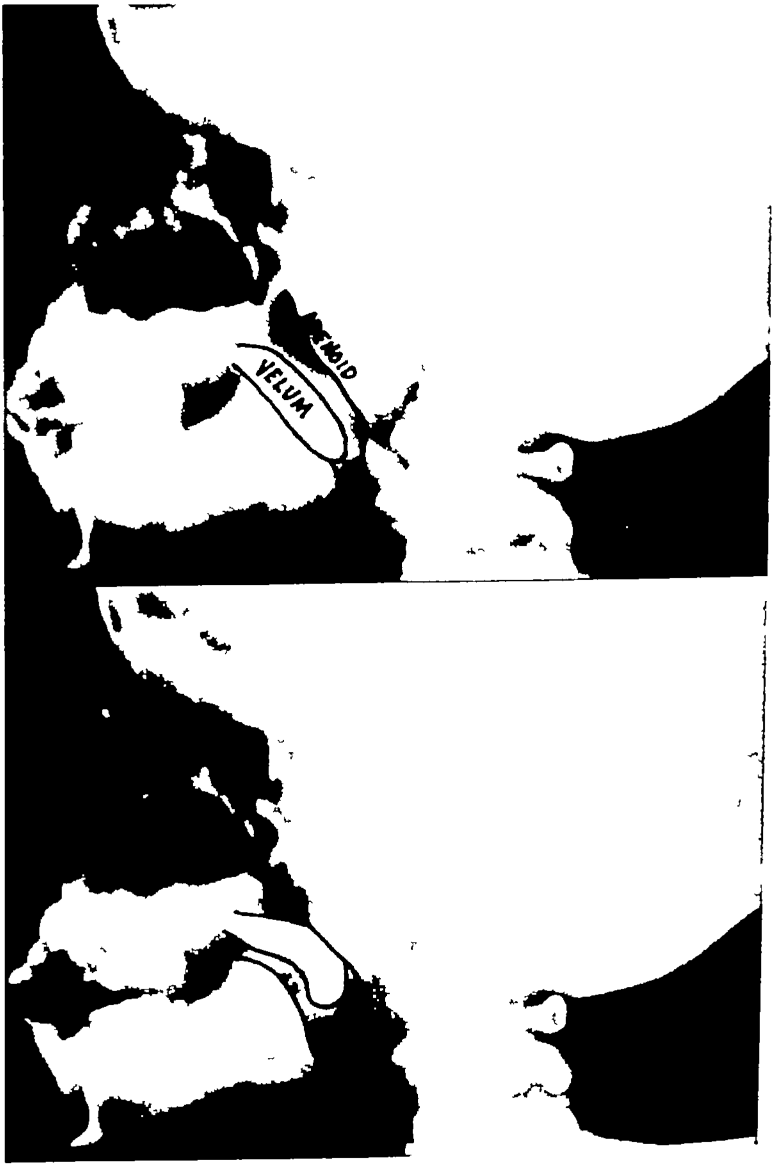

Fig 9 Palatopharyngeal valving in a child with an intact adenoid mass Note that during the sustained phonation of the vowel u as revealed in the lower illustration the soft palate makes contact against the adenoid projection into the nasopharynx rather than with the posterior wall of the pharynx.

tional displacement of the lower portion of the posterior lip In deglutition, there is an active movement of the anterior and posterior lips of the torus tubarius, associated with elevation and lateral retraction of the soft palate and floor of the tube Opening the tube during swallowing is not the result of simultaneous movements, but of a succession of movements of the tubal muscles There is an initial widening of the orifice of the tube, determined by the movement of the inferior edge of the posterior lip, due to active contraction of the rising salpingopharyngeus muscle While the soft palate and floor of the tube are elevated by the action of the levator palati, there is an outward movement of the lateral portion of the orifice of the tube due to the tensor muscle which afterward, when the palate drops, determines an anterior displacement of the tube, producing a deep and round opening

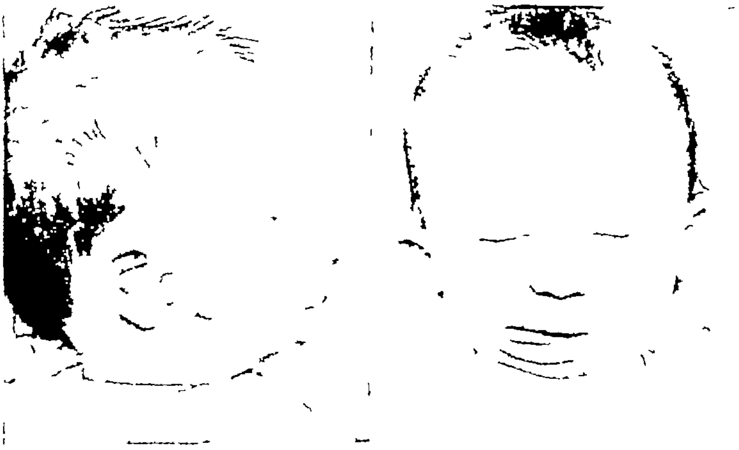

Fig 10

The Eustachian tube normally remains closed to shield the middle ear from pressure changes in the nasopharynx during quiet or forced respiration Palatal and tubal activity, as produced in phonation, does not cause opening of the tube, nor does sound pressure in the nasopharynx during phonation The tube as a rule opens during deglutition Swallowing liquid is most efficient in opening the tube In the reflex opening during swallowing the tube opens more widely than in voluntary opening

It is necessary to analyze the pathologic anatomy of cleft palate and the physiopathology of the Eustachian tube opening during deglutition According to Veau,[25] if a cleft is formed the aponeurosis does not develop, because it represents the consequence of the posterior pulling of the muscular sling The soft palate is, therefore, short, and the tendon of the tensor muscle, which has an abnormal oblique and upward direction, is inserted mainly on the posterior edge of the hard palate The action of the tensor palati on the velum is minimal in cleft palate, it may pull the velar tags forward and outward, causing the tips of the cleft uvula to point toward the midline On the other hand, arising partly from the posterior border of the hard palate it should be able to open the Eustachian tube orifice The activity of the levator palati becomes insignificant When present its action, associated with the one of the divided pterygopharyngeus segment of the superior constrictor, is to open the cleft more widely

Fig 11

The opening of the Eustachian tube orifice during deglutition appears definitely impaired in a cleft of the palate The levator palatini is unable to elevate the soft palate and floor of the tube The swallowing synergy is disturbed, and no reflex opening of the tube by means of the tensor muscle can be elicited The only active muscle in this mechanism is probably the salpingopharyngeus, which in some cases stands out like a band of muscular tissue on the lateral pharyngeal wall

Veau[25] maintains that palatal and pharyngeal muscles have a normal volume in a cleft palate fetus, however, with age, muscular atrophy develops secondary to the anatomical anomaly and inactivity, and the opening of the Eustachian tube will become more and more impaired It is particularly after a poor surgical result that atrophy reaches its maximum, the velum is whitish, tight and immobile

Fig 12

The idea that early closure would prevent muscular regression definitely fails to attain its goal when a poor result is obtained In these cases the dysfunction of the Eustachian tube is considerable, and a high percentage of ear pathology is recorded Even if a good surgical result is obtained, with restoration of the velopharyngeal sphincter, the dysfunction of the Eustachian tube is still great The division of the hamular process, advocated by so many surgeons, will release the tension of the tensor veli palatini and permit medial displacement of the velar tags restoring the velopharyngeal closure, however, the function of the tensor will be altered into an elevator, and no further lateral displacement of the lateral wall of the tube will be possible If a push-back or pharyngoplasty procedure is performed, the change of environment for palatal and pharyngeal muscles may result in a relative inactivity of the neuromuscular mechanism

Fig 13

On the other hand the action of the superior constrictor should be noted When compensatory hypertrophy of pharyngeal muscles develop and a considerable Passavant's ridge is seen, the medial displacement of the tubal cartilage and salpingeal folds unassociated with an anterior and outward shift of the tube impairs the opening of the Eustachian tube

If a patient is fitted with a speech aid, there is a possibility of ill-fitting and poor hygiene as a cause of impaired drainage of secretion, chronic pharyngitis and hyperplasia of lymphoid tissue

Nasal deformities were often found associated with alterations of nasal mucosa on a catarrhal or vasomotor basis In a certain number of patients, hyperplasia of tonsils and adenoids with accumulation of secretion in the nasal and nasopharyngeal cavities were observed In these cases the already impaired function of the Eustachian tube orifice becomes desperate and persistent, or recurrent middle ear disorders with hearing loss are the rule

Sataloff and Frazer[15] have advocated adenoidectomy in infancy at the time of the first palatal operation After the analysis of the multiplicity of factors involved in the middle ear disorders in cleft palate patients and the physiopathologic study of the Eustachian tube opening, it appears that adenoidectomy, in relation to speech rehabilitation, should be performed judiciously (see Fig 9) Special techniques directed toward the removal of the lymphoid tissue surrounding the Eustachian tube orifices, either surgically or with the use of a radium applicator, should be employed, when possible, in order to maintain the integrity of the velopharyngeal closure

Fig 14

Continuous otological study of cleft palate patients is of utmost importance When middle ear disorders develop, the several etiologic factors should be considered and removed, if possible Immediate treatment of the ear, nose and throat conditions is paramount in these children A hearing evaluation should be done as soon as possible To repeat—"Good hearing is essential to good speech"

CONCLUSIONS

1 Congenital anomalies of the ear are present in 2 per cent of all cleft palate patients and account for 13 per cent of associated anomalies to cleft palate They appear to be due to an arrest of development without a definite genetic basis

2 Forty-five per cent of cleft palate patients show definite evidence of ear pathology and 39 per cent have a definite hearing loss

3 There is no sex prevalence in the frequency of ear pathology in cleft palate patients

4 The middle ear disorders are predominantly bilateral with similar features in both ears There is no significant difference in frequency between purulent and catarrhal otitis media

5 The hearing loss is mild in more than one-half of the cases, moderate in about one-fourth of them Only about 4 per cent have severe hearing loss With the exception of five cases with a perceptive loss, all of the other cases have a typical conductive type of hearing loss with a similar pattern in both ears Close relationship is noted between the degree of ear pathology and hearing loss

6 The incidence of ear pathology is 6 per cent before one year of age, 27 per cent in pre-school children and 68 per cent in school children The incidence appeared to level off at this period

7 The frequency of ear pathology according to the type of cleft is strikingly uniform in school age children There is a smaller incidence of ear pathology in the clefts of the hard and soft palates in pre-school age children One-third of the cases with unilateral clefts of the lip and palate showed contralateral ear pathology

8 No definite relationship could be evinced between the width of the cleft and ear pathology

9 Surgical closure is related to a higher incidence of ear pathology in cleft palate children A correlation is noted between velar activity and frequency of middle ear disorders Early closure of the palate does not reduce the incidence of ear pathology

10 Ill-fitting or poor hygiene of speech aids interfere with nasopharyngeal physiology and may result in middle ear disorders

11 Nasal obstruction on an anatomical, catarrhal or vasomotor basis is a factor in the increased incidence of otitis media

12 Hyperplasia of the tonsils and adenoids is intimately related to middle ear disorders in a group of cleft palate patients

13 General factors such as prematurity, malnutrition and exanthemata surely predispose cleft palate children to a higher incidence of middle ear pathology

14 The pathogenesis of middle ear disorders in cleft palate patients is primarily related to a tubal dysfunction This dysfunction is definitely increased by all the above mentioned factors on a neuro-muscular or mechanical basis

15 The role of the otologist in a cleft palate care program is of extreme importance Continuous otologic vigilance of these children is a must Audiograms should be repeated at regular intervals Ear, nose and throat disease should be controlled immediately to prevent any further hearing impairment

SUMMARY

Otolaryngological implications in cleft palate patients have not been fully realized until recently A survey of the available literature fails to reveal an extensive study of ear pathology in cleft palate patients, 401 patients with various types of clefts are thoroughly investigated in the otolaryngological

field and receive accurate audiological study The anomalies of the ear associated with cleft palate are described, analyzed and discussed The higher incidence of middle ear pathology in cleft palate children than in normals receive a quantitative measure in this study The frequency of catarrhal and purulent middle ear infection is reported, as well as the frequency and nature of the hearing loss The several factors related to these findings are discussed in detail in the light of the statistical values age of the individual, type of cleft, width of cleft, surgical and non-surgical closure of cleft palate, nasal disturbances, hyperplasia of tonsils and adenoids, and general resistance The pathogenesis of middle ear disorders appears to be due to a Eustachian tube dysfunction, altered on a neuromuscular basis by the above factors

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PRACTICABILITY OF IMMEDIATE FENESTRATION AFTER STAPES MOBILIZATION FAILURE*

W P ANTHONY,

Fort Worth, Texas

INTRODUCTION AND EVOLUTION OF THE PROBLEM

The return to popularity of direct surgical attack upon the stapes for improving hearing in otosclerotic deafness came slowly After reading Rosen's[1,2] first articles on stapes mobilization, I was skeptical, because I felt that most stapes fixed by an otosclerotic process would not mobilize, and if they were mobilized, fixation would quickly recur Followup reports[3,4,5] confirmed my first objection to the procedure (a low percentage of good results), but other reports[6,7,8] refuted my second objection that results would be short lived, therefore, I decided to learn the necessary technique and acquire the necessary skill to practice this procedure The idea of practicing a procedure which would result in disappointment to approximately two-thirds of the patients operated on was so unpalatable, however, that in November, 1955, I decided to work out a stapes mobilization technique which would lend itself to immediate Lempert fenestration in case of failure

That is the background of the present study, begun in December, 1955, and continued with its interesting ramifications to the present

The problem of surgical technique, the first to present itself, was not exceedingly difficult to solve, and is reported in the first part of this paper under technique and presentation of cases

Establishing methods to determine accurately which stapes mobilizations were failures, and in which to proceed with a

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*Submitted as Candidate's Thesis to American Laryngological Rhinological and Otological Society Inc 1957

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fenestration, was the second and greater problem. This problem involves the patient whose stapes mobilization is apparently unsuccessful at the time of operation, but whose hearing is found to have improved considerably over the preoperative level weeks or months later. In such a case, an unnecessary fenestration would have been done. Because of this the combined procedure was abandoned.

The second part deals with the attempt to determine the incidence of this special problem, to solve it by establishing a criterion of failure or success of stapes mobilization on the table, and to evaluate this criterion by postoperative follow-up of a series of cases to which it had been applied.

REVIEW OF LITERATURE

Surgical attempts to improve conductive hearing loss by mobilization of the ankylosed stapes date from the work of Kessel[9] in 1876, when he tried to improve hearing loss resulting from infection by removing the drum, malleus, and incus. This method being unsuccessful, he later tried stapes mobilization and stapedectomy.[10] Boucheron[11] reported 60 cases in which he excised the posterior half of the drum, separated the incus from the stapes and mobilized the stapes. Miot[12] reported 200 cases of stapes mobilization in which he obtained only slight, temporary improvement in hearing. He believed that best results were obtained in early cases and that mobilization was not effective after complete ankylosis. Feraci[13] reported some success with mobilization. Blake,[14 15 16] Jack,[17 18] and Burnett,[19] in America, tried mobilization but eventually turned to stapedectomy performed through myringotomy incisions. The subject of oval window surgery disappeared from the literature after 1900. The following statement by Sourdille[20] is representative of the thinking that led to the abandonment of this type of surgical procedure:

> *The footplate of the stapes is so fixed by an osseous process and its crura so wedged in by the borders of the deformed oval window that extraction of the ossicle is practically impossible. If one exerts traction on the crura they are certain*

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Dr. Lempert,[35] who indicated, upon inquiry, that he did not do the stapes mobilization operation. More recently information has become available concerning this practice used by a few otologists in America and a number abroad, where it appears to be more popular.

Tato[36] (Argentina) states that he resorts to fenestration immediately if mobilization fails after every effort has been made, and that in cases of apparent mobilization with doubtful hearing gain he sometimes resorts to fenestration, according to personal impressions.

Wullstein[37] (Germany) frequently lists patients for stapes mobilization—possible fenestration, and in case of failure proceeds with fenestration. He makes the window in the knee of the external horizontal semicircular canal and covers it with a free graft.

Portmann[38] (France) reports that for stapes mobilizations he prefers a retro or suprameatal approach, with adequate removal of overhang for exposure of the round window. He dissects a long flap. He believes that this approach gives best conditions for working on the stapes and windows. He says, "In case of failure to mobilize the stapes and, if the round window is normal, it allows the opening of the oval window by resection of the affected footplate, or the possibility of immediately completing the operation by classical fenestration."

Cebrian[39] (Spain) says that, "When both crura are broken, the stapes or the incudostapedial articulation is luxated, or a noticeable hearing gain is not obtained, we immediately perform a fenestration so as to spare the patient a second operation." Cebrian[40] places great emphasis upon observation of the round window and its membrane as a criterion of success. He stresses that if the membrane or its light reflex can be seen to move when the stapes is palated, the stapes must surely have been mobilized.

In Canada, Smith[41] has combined the procedures. The only fault he and his associates have found with the combination procedure is the time consumed in shifting from one opera-

to be fractured and there is no other way of raising the foot-plate Besides, be assured that even if this could be done, the large communication established between the hole opened by the ablatum of the tympanus and the labyrinth will permit infection to enter and will thus lead to inevitable total deafness It was this simple conception which led in 1900 to an official condemnation of the operation which was so severe that we are still influenced by it 1937

The direct route to the inner ear having been abandoned, surgeons turned to fistulation of the horizontal semicircular canal Jenkins,[21] Barany,[22] and Holmgren[23 24,25] contributed to basic pioneering in this field Holmgren introduced microscope and magnifying glass to otosclerosis surgery Sourdille[26,20] developed a three-stage tympanolabyrinthopexy, which he reported at the New York Academy of Medicine, and Lempert,[27] in 1938, reported his practical one-stage procedure which with modifications, came to be the keystone of surgery for otosclerosis

In 1946, Lempert[28] reported a technique for detaching the tympanic membrane from its annular attachments as a surgical approach to the middle ear for tympanosympathectomy

In 1952, Rosen,[1] adapting Lempert's approach to the middle ear to verify the diagnosis of otosclerosis prior to fenestration, accidentally mobilized the stapes The patient's improvement in hearing was dramatic and long lasting

This inspired Rosen[2] to work out a stapes mobilization technique This technique has been modified and remodified by many authors,[29 30 31 32 33] and is now used by nearly all otologists before they consider the fenestration operation in cases of otosclerosis

At the outset of this investigation, the literature was completely silent about combining the stapes mobilization and fenestration procedures That Lempert[34] had spoken of such a procedure was known to me, however, a copy of his paper, "Evolutionary Progress in the Surgery of Middle Ear Deafness," presented in April, 1955, before the New York Academy of Medicine, was not available from the Academy or from either a stapes mobilization operation or fenestration operation were given a choice They could have the stapes mobilization operation by itself with the understanding that a fenestration would be done after the healing was complete, if the mobilization failed, or they could have the stapes mobilization procedure with preparation made so that, in event of failure, general anesthetic would be immediately administered and fenestration immediately performed

TECHNIQUE

Premedication Chlorpromazine hydrochloride (Thorazine) 25 mg is given intramuscularly 45 minutes preoperatively Another 25 mg ampule is sent to the operating room with the patient in anticipation of severe anxiety, or the occasional vertigo or nausea accompanying mobilization Chlorpromazine hydrochloride (Thorazine) tends to control anxiety without dulling the patient's senses to the point of uncooperativeness

With the patient under local two per cent lidocaine (xylocaine) hydrochloride and epinephrine anesthesia, a regular endaural incision is made A small amount of periostium is elevated posteriorly, and the outer thickened portion of the skin of the posterior external canal is trimmed A mastoid retractor is then placed and the wound opened widely A long flap is fashioned from the posterior skin of the canal from 12 to 6 (inferiorly) instead of from 9 (anteriorly) to 6 (inferiorly) as done regularly in the fenestration, to avoid an excess of redundant flap in the canal while doing the stapes mobilization The flap is lifted from the canal wall with the periosteal elevator and folded forward (see Fig 1) The posterior half of the drum is detached The detachment is not carried forward to nine o'clock anteriorly, as in the original Rosen technique, lest in rotating the flap into place following a fenestration one will put tension on the lower free portion of the drum, thus preventing its healing back to its inferior attachment, and thus producing perforation (combined technique Case 1), which is difficult to correct Bone is curetted posteriorly-superiorly, if necessary, for adequate visualization of the incudostapedial joint, stapedius tion to the other He believes that if the stapes appears to have been mobilized then one should not proceed with a fenestration regardless of audiologic findings

In the United States, Lindsay[42] has listed five cases to be done as combined procedures if the stapes fail to mobilize In two of them, the stapes mobilized and the procedures were discontinued In two cases mobilization apparently was not achieved, and fenestrations were immediately performed In the other case the stapes appeared to have mobilized satisfactorily, but the audiograms failed to indicate satisfactory improvement in hearing This confusion caused him to abandon the idea of the combined procedure

In the United States, also, Knight[43] has performed more than 39 immediate fenestrations after unsuccessful stapes mobilizations He says that by continuing the operation he has not had the problem of the disappointed patient after unsuccessful stapes mobilization Study of the footplate and oval window in these cases after removal of the bridge and a partial ossiculectomy has revealed that usually the crura were fractured and, even with excellent exposure, it was impossible to mobilize the footplate or to create a fracture across it

Fairior[44, 45] schedules cases having little chance for success with stapes mobilizations as exploratory tympanotomy and fenestration If he finds a small otosclerotic focus with easy mobilization, he stops If there is a large growth of bone which would necessitate a great deal of manipulation after which secondary closure would be likely, he proceeds with fenestration This he accomplishes by making the transmeatal portion of the regular fenestration incision, cutting a long flap, then doing the exploratory tympanotomy If the stapes mobilization fails, he makes the complete incisions and proceeds with the fenestration

PART I

MATERIAL AND METHODS

For nine months (December 15, 1955, to September 15, 1956) all patients who were considered good candidates for ical audiometry During this first period, various techniques of audiometry were tried in the struggle to find an infallible method When the mobilization result was questionable, fenestration was always deferred The problem of establishing a criterion will be taken up later under a separate heading.

RESULTS

Twenty-three patients were listed as stapes mobilization—possible fenestration during this nine-month period On the table, six cases appeared to be obvious failures, and immediate fenestrations were performed In 17 cases, the stapes mobilization appeared to be either successful or questionably successful, and immediate fenestration was not carried out. Four of this group were considered to be failures at the three-week postoperative audiometric check One appeared to be successful at three weeks, but had dropped back to the preoperative level in five months Three of these five failures submitted to later fenestrations carried out two to seven months postoperatively All were successful The previous long flap mobilization procedure did not interfere with subsequent fenestration in any way Cases done as a combined procedure are reported herewith

REPORTS OF CASES

Case 1 A white woman age 55 years was first seen in June 1953 for treatment of bilateral external otitis resulting from the use of a hearing aid Inquiry into her hearing problem revealed that she had had a bilateral progressive hearing loss accompanied by tinnitus for some 25 years

Physical examination of the ears nose and throat was negative except for mild external otitis which responded quickly to treatment Tuning fork tests and audiograms revealed a bilateral hearing loss averaging 62 decibels on the left and 60 decibels on the right in the speech frequencies Bone conduction audiograms indicated that the patient was a borderline Class A candidate for a fenestration on the left and Class C on the right Medical examination and laboratory tests as well as roentgenograms of the mastoids were negative A fenestration operation on the left was recommended but declined however two-and-one-half years later in January of 1956 the patient agreed to a stapes mobilization operation to be followed immediately by a fenestration in event of failure

Operation On January 17 1956 with the patient under local anesthesia an endaural incision was made and the usual fenestration flap was cut and elevated down to the annulus fibrosis posteriorly The posterior half of the tympanic membrane was then lifted out of its sulcus and folded forward to expose the middle ear The incudostapedial joint was found to be unusually far anteriorly so that it was impossible to place tendon, and stapes In all except two of these cases, the original Rosen[2] technique was employed for actual mobilization of the stapes

If the mobilization is successful, the long flap is replaced and packed in place lightly with cotton balls over surgical rayon

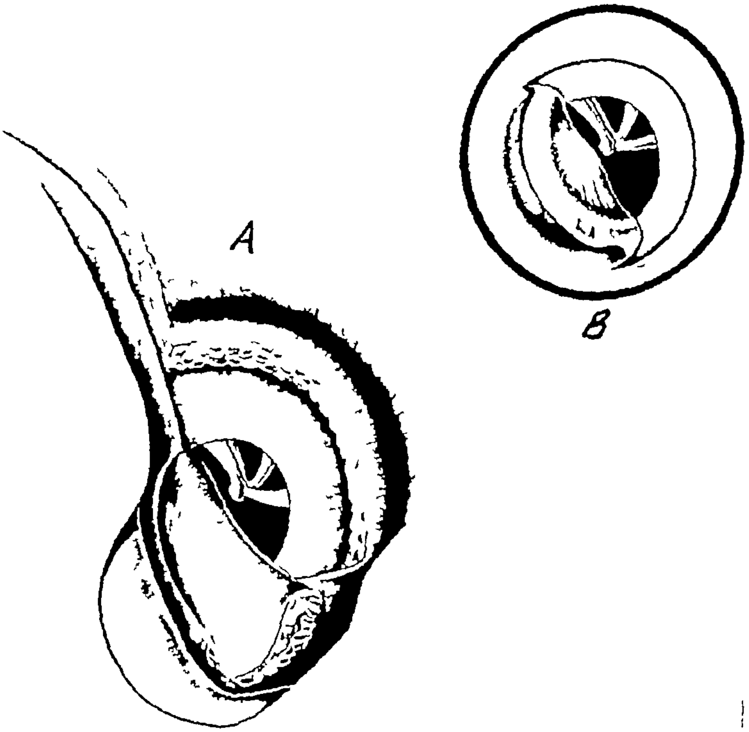

Fig 1—A. Incision used for stapes mobilization—possible fenestration procedure B Incision used for stapes mobilization only

If the mobilization is unsuccessful the incision in enlarged, the cortex is removed with the bur from the zygomatic route to the sinodural angle, and the usual fenestration is carried out, the flap having been previously dissected and fashioned

Criteria for success or failure of stapes consisted of visual and tactile observations of the stapes, spoken voice, and surg-

On February 1, 1956 with the patient under local anesthesia an endaural incision was made and a long flap elevated downward to the tympanic membrane The posterior half of the membrane was lifted away and folded forward, the incudostapedial joint was thus nicely exposed

The Rosen mobilizer was placed anteriorly on the neck of the stapes and posterior pressure was made This resulted in fracture of the crura without evidence of increased hearing The patient was then given thiopental sodium (Pentothal) by vein and intubated A fenestration procedure was done by the cupola technique of Lempert. When an attempt was made to fit the flap before completing the window it became evident that, in anticipation of a successful stapes mobilization and in an attempt to avoid the impediment of a redundant flap in the way for the mobilization the flap had been cut too short to cover the window properly, therefore a split thickness graft was taken from the inside of the thigh with an electric dermatone It was placed over the window and the area ordinarily covered by the tympanomeatal flap It was placed so as to cover the drum completely Two other portions were perforated and placed superiorly and posteriorly so that the complete cavity was covered by skin The graft was invaginated into the window and held by a small piece of cotton The cavity was packed with cellulose sponges and vaseline gauze over rayon strips

The outer dressing was removed on the fifth day as were the vaseline gauze and cellulose sponges The rayon strips and cotton were removed on the tenth day

Although the grafts seemed to take and the cavity became dry in time in nearly all the cavity the grafts have been replaced by mucus producing epithelium The central graft covering the window has remained A posterior inferior perforation of the drum has remained as in Case 1

Hearing improved to a 38 db average in the speech frequencies and the improvement has remained

Case 3 A white woman aged 32 years was first seen in December 1952 complaining of gradually progressive bilateral hearing loss associated with roaring tinnitus on the left. She said that this hearing deterioration had begun about 18 years previously She heard better in noisy rather than in quiet places

Physical examination was not remarkable Tuning fork tests and audiograms revealed a bilateral conductive deafness averaging 55 db on the right and 60 db on the left in the speech frequencies Bone conduction audiograms indicated that the right ear should be considered Class A for fenestration and the left a Class B for fenestration Medical examination routine laboratory tests and roentgenograms of the mastoids were normal

A fenestration on the right was recommended but never accepted The patient returned in December 1955 however requesting a stapes mobilization and consented to a combined procedure if the stapes mobilization failed

On February 3 1956 with the patient under local anesthesia an endaural incision was made and a self retaining mastoid retractor was placed The long fenestration flap was elevated down to the tympanic membrane which was in turn lifted from its sulcus from 12 to 6 o clock posteriorly The Rosen mobilizer was placed on the neck of the stapes anteriorly and pulsating pressure made posteriorly The crura fractured There was no subjective improvement in hearing A fenestration was then carried out without incident while the patient was under general anesthesia. Postoperative recovery was uneventful the Rosen mobilizer properly on the neck of the stapes to make posterior pressure The crura were fractured eventually without improvement in hearing after an attempt to mobilize the stapes by anterior pressure at the neck

Thiopental sodium (Pentothal) was administered intravenously, an intratracheal tube was inserted and from this point a fenestration operation was performed in the usual manner The window was made by the cupola technique of Lempert, and the flap was invaginated into the window In rotating the flap after this type of dissection (drum separated to or past six o'clock (anteriorly), the posterior inferior drum margin tends to stretch fairly tightly and to pull away from the tympanic sulcus so as to produce (as in this case) a perforation difficult to heal

Postoperative recovery was uneventful Secondary split thickness graft from the inside of the upper arm was laid into the cavity on healthy granulations on the twelfth postoperative day and healing was prompt As the cavity dried out and healed a wedge-shaped posterior inferior perforation was seen to exist This resulted in failure to obtain serviceable hearing

On April 13, 1956, three months after the fenestration on the left a stapes mobilization was attempted on the right. It also failed because of the anterior placement of the stapes as on the left, which made manipulation by the Rosen technique impossible *

Sporadic attempts to close the perforation in the left failed because the patient was unable to return regularly for treatment

In January, 1957 one year after her fenestration operation the perforation was grafted by the method of Wright [46] The cavity was exposed by incising through the old scar superiorly and spreading the meatus with a self retaining mastoid retractor With this exposure, the epithelium was removed about the perforation for a distance of 5 6 mm with the angled chalazion curettes A small split thickness graft was removed from the non hair bearing skin of the mastoid process laid over the perforation and made to overlap the perforation by 6 7 mm in all directions The graft was held in position by small cotton balls placed against it lightly without pressure

The patient left the hospital on the second postoperative day The cotton balls and sutures were removed on the fourth day The hearing level now averages 22 db in the speech frequencies two months post operatively The cavity is dry and the tympanic membrane is intact

Case 2 A white woman, aged 48 years first seen in January 1956 complained of bilateral deafness of about twenty years' duration She denied pain discharge or vertigo but said that she had a roaring tinnitus most of the time Her hearing defect had at first been rapidly progressive but had not seemed to change in recent years

Physical examination was not remarkable Tuning fork tests and audiograms revealed a bilateral conductive hearing loss averaging 55 db on the right side and 57 db on the left Bone conduction audiograms indicated that the right ear fell into Class B and the left Class A for fenestration Medical examination, laboratory tests and roentgenograms of the mastoids were normal

The right, or poorer ear was selected for operation An immediate fenestration was recommended if a stapes mobilization failed to improve hearing on the table not going ahead with the secondary fenestration procedure if the least possibility of a successful mobilization existed Technique had ceased to be a problem

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*This stapes was successfully mobilized recently by transincudal pressure with the Derlacki mobilizer

Discussions at the meeting of the American Academy of Ophthalmology and Otolaryngology in October, 1956, (House[47] and Kos[48]) brought out a possible situation that I had not encountered in my practice What about the patient who apparently has no improvement at the time of mobilization but later, up to three months, demonstrates a strikingly successful result? These "sleepers" could be unnecessarily subjected to fenestration by combining the two procedures unless more accurate means of evaluating results on the table could be found

Baron[49] also had spoken out against the combined procedure He presented one case in which the crura were fractured, but the footplate was mobilized Surgical audiometry immediately after the procedure showed a very poor result, the hearing was worse Two weeks postoperatively an audiogram revealed that the air-bone gap had been closed On this basis, Baron concluded, "The evidence here is clear that one cannot tell at the time of surgery whether or not the mobilization is successful" He believed that fenestration should always be deferred until results of stapes mobilization can be properly evaluated

I abandoned the combined procedure pending further evaluation of this new problem, which I had not recognized

Whether I had done unnecessary fenestrations, or could possibly do them in my present mode of practice and, if so, what I might do to prevent such errors became a pressing issue, therefore, I decided on two studies

1 I would run a series of cases of stapes mobilization only At the time of operation, I would apply all criteria and judgment at my disposal On this basis, I would decide whether or not a fenestration should have been done in each case had it been scheduled as a combined procedure Then I would compare these on-the-table judgments with postoperative

Secondary skin grafts were laid into the cavity on clean granulations on the eighteenth day after operation Healing was satisfactory Hearing has improved and been maintained at the 25 decibel level in the speech frequencies

Case 4 A white woman, age 50 years, first seen on March 17, 1956 complained of hearing loss for 25 years She said that the loss had been progressive and accompanied by occasional roaring tinnitus, and that she had worn a hearing aid for two years

Physical examination of the ears, nose and throat was normal Tuning fork tests and audiograms revealed a conductive deafness of 55 db in the speech frequencies on the right and 48 db on the left Bone conduction audiograms indicated that she would be a Class A candidate for fenestration in either ear Discrimination scores were 84 per cent right and 88 per cent left

A stapes mobilization was recommended on the right (poorer ear) to be followed immediately by a fenestration in case of failure

On May 19, 1956, while the patient was under local anesthesia, an endaural incision was made and fenestration flap was elevated The posterior half of the membrane was freed and folded forward The incudostapedial joint was well visualized after curettage posterosuperiorly The mobilizer was placed anteriorly on the neck of the stapes Posterior pressure produced motion of the head posteriorly, but neither voice response or pure tone audiometry in the speech frequencies indicated any improvement in hearing A fenestration was, therefore, carried out with the patient under general anesthesia It was without unusual incident as in the previous cases, and postoperative recovery was uneventful The cavity was secondarily grafted with split thickness grafts from the inner surface of the arm on the sixteenth day The cavity healed quickly Hearing improved to a 20 decibel average loss in the speech frequencies, and the improvement has been maintained

Cases 5 and 6 are in no way essentially different from Case 4 In both cases, the Rosen maneuver resulted in fracture of both crura Voice tests, as well as pure tone audiometry, indicated that no improvement in hearing had been obtained Fenestrations were done, the cavities secondarily skin grafted, and anticipated improvements in hearing were obtained and have been held

No loss of cochlear function in any of these six cases was observed in postoperative bone conduction audiograms

PART II

THE SPECIAL PROBLEM OF ESTABLISHING AND EVALUATING CRITERIA OF SUCCESS OR FAILURE OF STAPES MOBILIZATION AT THE TIME OF SURGERY

Up to this point, a combined procedure apparently had no major disadvantages if one erred on the side of safety in

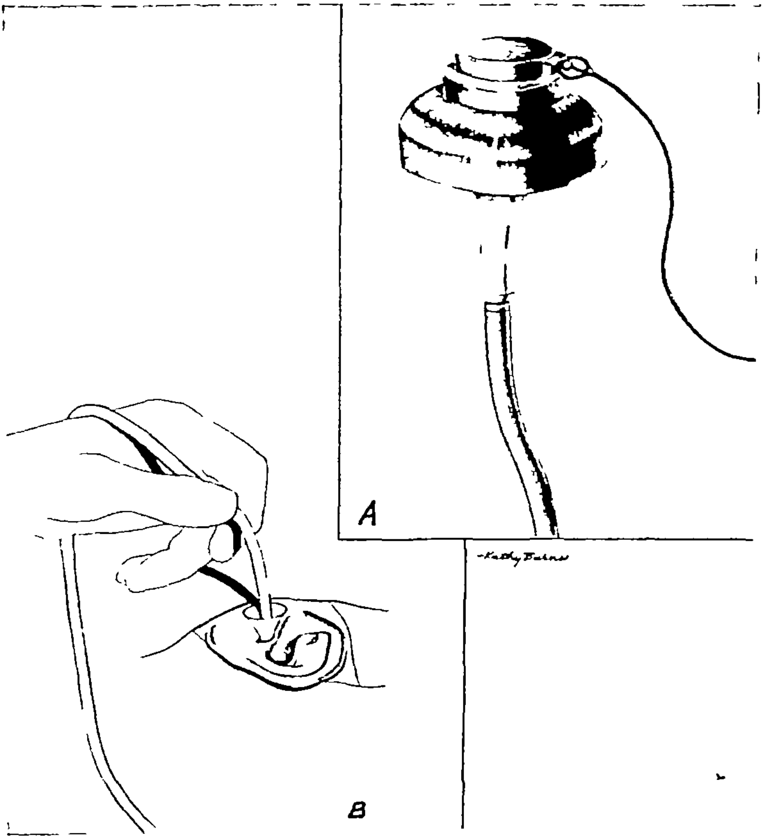

Fig 2—A Audiometer receiver with stethoscope bell and tube firmly fixed to face B End of rubber tube placed in ear speculum during testing

important in guidance as the average amplitude of response" They used the Fletcher[51] formula for converting pure tone threshold to an equivalent speech reception threshold This is done by averaging the two best responses of the three (500, 1000 and 2000) frequencies tested for an SRT, or single "figure of merit" for comparison of steps in the surgical audiometric procedure The analysis of Goodhill and Holcomb[30] of 20 typical successful stapes mobilizations showed a gain of 5 db at 500, 10 db at 1000 and 10 db at 2000 between stage 2 and 3 (the critical stage), therefore, I adopted the routine of "direct vision" audiometry, doing pure tone thresh-

audiograms I *would try to correlate* percentage of on-the-table errors in judgment with criteria applied

2 I would question other *otologists* about criteria of success and the incidence *of apparent* failures on the table resulting as successes postoperatively

THE DIRECT VISION TECHNIQUE IN SURGICAL AUDIOMETRY

Early in my experience with surgical audiometry, I had noticed that the windows would not infrequently fill with blood during the long *period of testing when the middle ear was hidden from vision by a sterile* towel and audiometer receiver Distrusting the audiograms obtained by this means, I devised a "direct vision" technique of "comparative surgical audiometry"

An A D C portable audiometer was used The circular rubber ear mold was removed from the receiver or earphone A stethoscope bell with a detachable 18-inch rubber tube was placed firmly *against the center of the face of the* receiver, and the rubber mold was then replaced tightly supporting the stethoscope in position firmly against the ear piece (see Fig 2) The rubber tube was kept sterile and attached to the bell by a Luer-Lok only when testing The stethoscope bell and rubber tube guided the sound directly to the ear *speculum, which remained in place*

The 10-15 db dampening effect of the rubber tube on the sound was such that audiometric *measurements* done in this *way could not be compared accurately* with preoperative audiograms, and it was used only to compare the second (*drum* off premobilization stage) with the third (drum off post-mobilization stage) and was, therefore, referred to as "comparative audiometry" only Between each change in intensity of each frequency, the tube could be removed from the speculum *and the windows examined, thus the term* "direct vision" audiometry This *method also had the advantage* of cutting out extraneous noises in the operating suite during testing

Goodhill and Holcomb[50] *pointed out that*, "Discrete frequency characteristics in surgical audiometry are not as was defined as an average 10 db or more gain in the speech frequencies over the preoperative average In these patients unnecessary fenestrations could have been performed if they had been scheduled for combined procedures and no other criteria had been relied upon In all four patients, visual and tactile impressions, as well as response to voice tests, indicated that mobilization of the stapes had been accomplished This criterion accurately indicated success in 35 patients or 53 8 per cent, and accurately indicated failure in 10 patients or 15 4 per cent It inaccurately predicted success in seven patients who showed no improvement at the three-month check

Audiometry could not be carried out in 9 of the 65 patients (13 8 per cent) for the following reasons

1 Oversedation in two patients

2 Excess bleeding in one hypertensive patient in whom adrenalin could not be used for hemostasis

3 Audiometer out of repair when two patients were operated on

4 In one patient, the stapes was inadvertently mobilized by transincudal pressure in obtaining proper exposure by curettage

5 Three patients were so deaf that the 10-15 decibel dampening effect of the tube on the sound transmitted through it made premobilization audiometry impossible by the "direct vision" technique

THE QUESTIONNAIRE

In May, 1957, while the foregoing data were being accumulated, an attempt was made to find out how other otologists were solving these problems of surgical audiometry, criteria of success, and the problem of the patient with apparent failure who later gained hearing I wanted to see also whether there existed any particular criterion or method of audiometry that uniformly and accurately predicted success or failure on the table in the hands of more than one otologist olds only twice, once just before mobilization and again immediately after mobilization The tests were repeated after successive mobilization attempts if necessary Only the frequencies 500, 1000 and 2000 were tested If responses for the second audiogram were 10 db better than the first in any two frequencies, the case was recorded as "successful" Any less improvement was recorded as "failure" Since the adoption of this technique and this criterion of success, 65 stapes mobilizations have been performed No combined procedures have been done, but at the time of the three-week postoperative audiogram and again at the three-month check I asked *On the basis of the criterion employed and its results at the time of operation, could an unnecessary fenestration have been performed?*

TABLE I

Results of Direct Vision Technique of Surgical Audiometry in 65 Consecutive Cases of Stapes Mobilization

Inapplicable for various reasons	9, or approximately	13 8%
Accurately predicted success in	35, or approximately	53 8%
Accurately predicted failure in	10, or approximately	15 4%
Inaccurately predicted success in	7, or approximately which were failures at three-month check	10 8%
Inaccurately predicted failure in	4, or approximately which were successful at three-month check	6 2%
	65	100 0%

RESULTS OBTAINED BY USING DIRECT VISION AUDIOMETRY AS A CRITERION

An attempt was made to use the direct vision technique of surgical audiometry in 65 consecutive patients (see Table I) in whom stapes mobilizations were done between July 1, 1956, and June 15, 1957 In four patients, or 6 2 per cent, this criterion inaccurately indicated failures at the time of surgery but later audiometric tests (*three months postoperative*) indicated that the operations had been successful Success

No generalizations were possible about criteria, but three points were of interest *1* The four otologists who stressed visualization of the footplate and round window reported considerably less than average errors in prognosis on the table, *2* It may be quite significant that the otologist who uses the pattern of sound coming from a vacuum pump reported no failures on the table who have later gained hearing, *3* Of the two otologists stressing reversal of the Rinné test, one reported 2 per cent failures on the table—later hearing—the other reported "very few "

Additional comment on the overall subject of the combined procedure was very interesting and raised many interesting thoughts

Enthusiastic about the combined procedure	3
Adamantly against	3
Generally favorable to the idea	6
Skeptical because of specific problems that came to mind	18
Interested but no special feeling pro or con	20

One otologist very significantly pointed out that since simple stapes mobilizations have been known to produce cochlear damage, it would be worse to attack the labyrinth twice at one sitting

Three otologists regularly schedule cases as stapes mobilization possible fenestration

One objected to the combined procedure because it defeats the simplicity which characterizes the stapes mobilization procedure

Two felt that a combined procedure would solve the problem of the stapes mobilization failures who will not return for fenestration

One said that the combined procedure "saves the patient a gamble "

Two expressed fear that the flap might not fit

Four objected on the basis of the difficult psychological and

Letters were sent to 88 otolaryngologists known to me personally to be doing otosclerosis surgery or assumed to be doing this surgery by virtue of membership in the Otosclerosis Study Group A brief explanation of the problem was given, and the following information was requested

1 In how many, or in approximately what percentage of your stapes mobilizations have you observed late hearing improvement in cases which were apparently failures at the time of operation?

2 What criteria were employed at the time of operation to decide whether the procedures were or were not successful?

3 Any additional comment you care to make concerning a combined stapes mobilization fenestration procedure would be greatly appreciated

More or less complete replies were received from 50 otologists The percentage of apparent failures improving later was given anywhere from 0 per cent to 42 per cent The median was 7 5 per cent of total cases Most percentages given were approximations rather than actual counts

As for criteria, 26 used some form of pure tone audiometry, and 10 of them specified four-stage audiometry Eleven indicated that voice or speech tests were employed with the audiometry Six used voice tests only

Four stressed the use of tuning forks, and two laid heavy emphasis upon reversal of the Rinné test as a criterion

One surgeon ingeniously and uniquely uses a Sorenson rotary electric vacuum pump which has a low hum Before the operation, this surgeon asks the patient if he can hear the hum of the machine and repeats the question after the stapes is mobilized All of this otologist's patients in whom mobilization was successful have been able to hear the pump He has had no late successes which were *thought to be failures* on the table

Four stressed visualization of the footplate and round window membrane tration so formidable or destructive that its performance in this small percentage should contra-indicate an otherwise reasonable and advantageous system of practice? At this point, no strong contra-indication to the combined procedure seems to exist The choice of procedure evolves as one of personal preference

In patients in whom fenestration of the oval window, chiseling, or other excess trauma to the footplate is anticipated, a fenestration should not be considered for fear that two inflammation-producing assaults upon the labyrinth might result in loss of cochlear function It is because of the increasing popularity of these footplate procedures that the combined procedure is not likely to come into general use

DISCUSSION

When one considers whether to practice separate stapes mobilization and fenestration procedures or the combined procedure, a host of major as well as minor advantages and disadvantages of the two concepts becloud one's judgment The individual otologist must place them in proper perspective in making his own decision Having temporarily discontinued practicing the combined procedure for approximately one year while collecting data for a part of this study, I find it difficult to decide whether or not to resume the procedure

The following factors must be evaluated in making a decision

1 Failure to hear after stapes mobilization has a bad psychological effect on the patient Failure occasionally may result in bitterness, but more often in loss of confidence in surgery as a means of rehabilitation The patient then is deprived of having serviceable hearing ultimately restored by returning for fenestration or stapes mobilization of the opposite ear Even in the patient who plans to go ahead with further surgery after a stapes mobilization failure, the anxiety and waiting between operations in undesirable and is avoided by the combined procedure

2 Cost to the patient in time and money is increased by economic problems involved in preparing a patient for a major or a minor procedure with subsequent long or short hospital stay

Three objected on the basis of the difference in premedication for two procedures, that is, a patient premedicated only for a stapes mobilization is not prepared for fenestration, also, some operators sedate stapes mobilization patients so heavily that they cannot reliably respond to hearing tests upon which the decision to fenestrate may be based

One objected that unnoticed blood in the middle ear might interfere with the accuracy of the audiograms

Three suggested parts of the following thought that footplate perforation, stapedectomy, and other such surgical attacks upon the oval window would not only render the hearing tests unreliable as far as predicting ultimate success of the operation, but also supplant the classical fenestration operation as a secondary procedure in case of failure of simple mobilization

One objected to excess bleeding and unwieldiness of the large flap

Under additional comments, the dangers of stapes mobilization were stressed Two otologists knew collectively of four dead labyrinths and one fatal meningitis resulting from stapes mobilization operations

CONCLUSIONS

The problem of technique, in combining the stapes mobilization and fenestration procedures if the former fails, lends itself to simple solution It may be considered practical

The special problem of establishing adequate criteria upon which to base the decision to proceed with the fenestration appears to be surmountable With adequate magnification, illumination, and exposure combined with painstaking direct vision audiometric control, very few patients submitting themselves to such a stapes mobilization-possible fenestration procedure would be unnecessarily fenestrated Is the fenesery has affected and will have further impact upon the concept of the combined stapes mobilization and fenestration procedure

a Perforation of the footplate[31 52] may result in improved hearing on the table with later loss, and may thus cloud the criteria of success at the time of operation This situation could not result in unnecessary fenestration, however, because the error would encourage failure to do a needed fenestration

b If simple stapes mobilization has been known to produce dead labyrinths and fenestrations only have been known to produce dead labyrinths, then combining these procedures might be expected to increase the number of these catastrophes The combined procedure, however, should be safe in cases in which the footplate is heavily overgrown and surgical attack is not attempted, or where it is attempted and found to be futile Good magnification and exposure are most important

c The practice of removing the stapes, as suggested by Portmann and Claverie,[53] Rambo,[54] Wullstein,[54] and Shea,[54] could conceivably result in all manipulations being confined to the oval window in the future If stapes mobilization fails, the stapes is removed *in toto* Then the stapes is replaced with "plastic substitution" (Wullstein, Shea), or the ear drum is placed directly over the opened oval window (Rambo), or a portion of a previously fashioned large tympanomeatal flap is invaginated down into the middle ear over the opened oval window (Portmann and Claverie) The general adoption of this concept would eliminate completely the use of a combined stapes mobilization, fenestra-nov-ovalis operation

6 Unfortunately all patients on whom combined procedures are anticipated must have regular endaural incisions which prove to be unnecessary in the majority of patients who ordinarily require only stapes mobilization Thus the patient whose mobilization is successful is penalized by the necessity of a mastoid dressing, extra trauma, bleeding and pain

7 The fashioning of a long tympanomeatal flap prior to two hospital admissions and two operating room charges The combined procedure is more economical for patients requiring two operations

3 The length of time consumed in performing a combined operation is very great, especially if a number of attempts are made to mobilize the stapes and each attempt is followed by an audiometric check A surgeon may very well be exhausted by the time he must perform the most critical part of the fenestration operation Great inconvenience to all persons concerned with the use of the operating room is caused by scheduling patients for combined procedures, because the time involved is unpredictable, it may range from a few minutes to all morning If there is any possibility that a patient scheduled as combined will require fenestration, the surgeon can scarcely list more than one patient in a morning Of course, the problem created is no greater than that frequently encountered in cancer surgery in scheduling a patient for biopsy and possible radical lymph node dissections

4 Sedation must, to a degree, be sacrificed if the patient is to be alert and cooperative enough to respond accurately to audiometric examination on the table I suspect that many prognoses of failure made on the table and later refuted were the result of heavy sedation The practice of giving only 25 mg of chlorpromazine hydrochloride intramuscularly before operation had seemed to allay the patient's tensions but leave the patient alert enough to be checked audiometrically If considerable nausea or vertigo occur or the patient becomes tense, another 25 mg of chlorpromazine hydrochloride may be given intramuscularly or intravenously

I have used 10 mg of prochlorperazine (Compazine) recently instead of 25 mg of chlorpromazine hydrochloride (Thorazine) The pharmacologic action is essentially the same, but the danger of the occasional jaundice following the use of even small doses of chlorpromazine hydrochloride is avoided

5 The increasing popularity of footplate perforation and stapedectomy in the rapidly changing scene of otologic surg-nificant minimum Though tests performed by this technique would seem to be rendered ineffective by the lack of sound protection for the round window during the test, nevertheless, its relative reliability is supported by clinical observation when it is performed as described

The recent tendency has been for stapes and oval window procedures to become bolder and consequently more traumatic. Though these new concepts are titilating to the curiosity and inventive genius of otologists few can be considered atraumatic, well controlled, or likely to produce high percentages of long lasting results The disappointing history of stapes mobilization and oval window surgery in general, prior to the turn of the Century, may well be upon the threshold of repeating itself Let us hope that some middle ground may be found before these procedures are once again "officially condemned" as in 1900 To the otologist the labyrinth should be held near sacred If we are to defile it, should it not be by way of the well controlled classical fenestration operation which time has established as a highly successful and relatively safe procedure? The concept of the combined stapes mobilization fenestration procedure offers a safe middle ground if the operator confines his efforts at mobilization to simple maneuvers which produce only minimal trauma. It would offer a safe middle ground for all operators, even those who prefer radical footplate procedures, if only adequate criteria could be developed by which an operator might know with reasonable certainty, in which cases the stapes might mobilize with minimum trauma and in which cases even radical procedures would be useless Time may give these answers

SUMMARY

Occasionally in this country, but more frequently abroad, the stapes mobilization is immediately followed by fenestration in case of failure This paper attempts to evaluate the practice and the rationale underlying it A technique developed for such combined procedure is described Twenty-three consecutive operations listed as stapes mobilization stapes mobilization has advantages and disadvantages In a narrow canal, the long flap may be redundant and awkward, and may to some degree obstruct vision On the other hand, with this type of preparation, bone may be removed without difficulty for better exposure I, personally, feel that visualization and maneuverability of instruments are easier than through the speculum as employed in the regular technique This freedom of motion is especially helpful in curetting the overhang postero-superiorly for better exposure of the incudostapedial joint and stapedius tendon

a In an attempt to avoid the long redundant flap, one is tempted to cut it too short to cover the fenestra adequately (Case 2), and one must then use a free graft This pitfall is solved by experience Knight[43] has not encountered this difficulty in more than 39 operations

b Another pitfall in technique is inadvertently creating a postoperative postero-inferior perforation of the drum If the drum is detached inferiorly anywhere nearly as far forward as Rosen[1,2] described in his original technique, the inferior part will pull away from the bone inferiorly when the flap is rotated This defect is not obvious at the time, but it is apparent postoperatively (see Case 1)

c An advantage of the longer flap is evident when an inadvertent tear in the posterior part of the drum occurs Sliding the long flap medially provides adequate extra skin so that the raw edges of the tear may be overlapped

8 Those who, after failure to mobilize the stapes, prefer to attempt the opposite ear and again re-enter the first ear for revision prior to fenestration, will find little use for a combined procedure Either the surgeon will eventually succeed in obtaining hearing by stapes mobilization only, or the patients will give up

I do not believe that the "direct vision" technique of surgical audiometry, or any form of audiometry, is a panacea for determining success or failure of a stapes mobilization at the time of operation It has, however, in combination with visual and tactile impressions, reduced any margin of error to an insig-

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possible fenestration, of which six were actually performed as combined procedures, are reported

The special problem of developing criteria to determine at the time of stapes mobilization if fenestration is necessary is discussed A "direct vision" audiometry technique is described and suggested as one criterion This criterion was evaluated by applying it at time of operation to 56 stapes mobilizations cases and comparing its prognosis to the final outcome of the cases This audiometry technique appears to be a reasonably accurate indicator In this series of 56 cases only four, or 7 1 per cent, would have been unnecessarily fenestrated, even without the aid of visual and tactile impressions and voice tests which belied the audiometric findings in these four cases A fenestration would have been done on none of these patients

Analysis of questionnaire responses from 50 otologists failed to reveal an on-the-table criterion for predicting postoperative results of stapes mobilization which was uniformly accurate in the hands of different otologists Using various combinations of criteria, the median per cent of errors in judgment, which could have resulted in unnecessary fenestrations, had the combined procedure been used was 7 5 per cent

An attempt is made to review and discuss the many facets of the case for and against the concept of a combined stapes mobilization fenestration It is concluded that this choice will remain one of personal preference, for there is no strong, firm contra-indication to a combined procedure except when extensive traumatising footplate work has accompanied the stapes mobilization procedure No loss of cochlear function was observed in postoperative bone conduction audiograms in any of the six patients on whom the combined stapes mobilization fenestration procedure was performed

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ALUMNI ASSOCIATION OF THE NEW YORK EYE AND EAR INFIRMARY

The Annual Spring Meeting of the Alumni Association of the New York Eye and Ear Infirmary last April was so well received that it has been decided to expand next year's meeting, which will take place from April 20-23, 1959

Symposia and lectures on Hearing Rehabilitation, Endoscopy, and Ear Surgery will be conducted It is also planned to offer refresher courses in Mastoid and Fenestration Surgery and Stapes Mobilization Techniques

More complete information regarding the meeting will appear in a later issue of THE LARYNGOSCOPE

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be, 5 No confusion of the patient, and no need for his assistance, therefore, no difficulty in cases of paralysis, tremors, etc.

Disadvantages The salpingoscope is larger, heavier and more expensive than a simple ear tube

Inflation of difficult patients In this connection, I may repeat two modifications of simple tubal inflation which were published in the *Monatsschrift fur Ohrenheilkunde,* Vol 78, p 146, 1944 As is well-known, some apprehensive or nervous patients frustrate the attempt at tubal inflation by relaxation of the soft palate Instead of elevating the velum during the enunciation of certain palatal speech sounds, such as "kay-kay-kay," they maintain it in a flaccid state In this way, they suddenly present the abnormal articulatory condition of functional rhinolalia aperta This causes the inflation sounds "kay-kay-kay" to assume a nasal quality, and prevents the very purpose of tubal inflation Since the inflated air then escapes behind the descended velum into the pharynx, no pressure builds up in the nasopharynx to open and penetrate the Eustachian tubes Obviously, this irrational action represents the patient's unconscious defense against the remedial maneuver of which he is afraid Once he has established this conditioned reflex, it is not always easy to re-educate the patient to the correct inflation, and the more complex catheter inflation may be necessary Needless to state that an apprehensive patient is even more fearful of this instrumental tech-

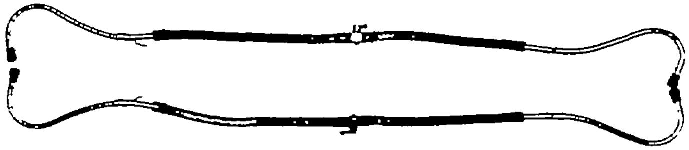

Fig 1 Differential salpingoscope Note the two one-way stop cocks which permit three choices of right monaural left monaural and binaural auscultation

DIFFERENTIAL SALPINGOSCOPE, A NEW DEVICE FOR TUBAL AUSCULTATION*

GODFREY E ARNOLD, M D ,

New York, N Y

After a century of Politzer inflation, word seems to have gotten around to some of the patients when to say "cuckoo" or "kay-kay-kay," but many still have trouble with holding the otoscope tube in their ears The tube also tends to fall out of the doctor's ear at the moment when he holds the catheter in place with one hand and reaches for the balloon with the other, not having a third hand to catch the dangling ear tube To obviate such needless aggravations of daily office work, I assembled a more practical device for tubal auscultation (see Fig 1) It consists of two pairs of binaural ear-pieces similar to a stethoscope Each ear olive of one set is connected to the homolateral olive of the other set by means of a rubber or plastic tube The two tubes between the two sets of ear olives are interrupted by one-way stop-cocks which allow the occlusion of one or both tubes One set with the black olives is introduced into the patient's ears, the other with the white olives is placed in the doctor's ears The device may be ordered from Storz Instrument Co , St Louis, Mo

Advantages *1* The physician's ears are partly masked for ambient noise, making it easier to concentrate on the tubal sounds, *2* Binaural auscultation of both tubes, simultaneously or alternatively, gives more audible information on the tubal function, *3* Simultaneous binaural auscultation provides immediate and impressive comparison of the two tubes particularly regarding temporal, qualitative or quantitative differences of their patency, *4* The self-retaining ear sets cannot fall out, no matter how narrow some ear canals may

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*From the Department of Research New York Eye and Ear Infirmary Technical report on studies undertaken with the aid of the Hartford Foundation

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the soft palate by the left thumb and index finger This causes the palate to contract and to occlude the nasopharynx In case of organic paralysis, the same maneuver is used for the passive elevation of the flaccid velum At the same time, the third left finger occludes the patient's right nostril The left fourth and fifth fingers find support on the patient's right cheek Inflation is then effected by the right hand, using a standard Politzer balloon with a rigid tip and detachable nose olive

Advantages Prompt and rapid inflation of uncooperative or fearful patients, including children, or in cases of organic palatal paralysis The patient has nothing to do but to open his mouth

Disadvantages Not suitable in the presence of violent gag reflex

Inflation during continuous articulation Some patients behave awkwardly when told to say "kay-kay-kay" at the moment of inflation In such cases it is easier to utilize a fricative sound of longer duration for the elevation of the palate As is well-known to phonetic specialists, the strength of palatal occlusion is different for the various speech sounds While it is quite weak for the vowels, particularly for the "ah" sound, the occlusion power is highest for the sibilant sounds, hence, a prolonged unvoiced "sss" usually produces the strongest contraction of the palatal valve The palatal "k" sound is characterized by a lower pressure When a patient is instructed to pronounce a prolonged sharp "sss," it is very easy to inflate his tubes during this relatively long period of articulation His palate remains firmly contracted until he pauses to take a breath, and the physician does not have to concentrate on a precise synchronization of the "kay-kay-kay" with the moment of inflation, further, a sibilant sound tends to produce a very firm palatal occlusion which counteracts a timid patient's escape into the protective state of functional hypoinnervation of his palate

Advantages *1* Sibilants produce the strongest palatal contraction which is desirable for effective inflation, *2* They can be pronounced during a long period of time (10-20 sec) nique In such cases I use two physiologic principles to overcome the undesired relaxation of the soft palate

Inflation during reflex innervation It is a basic law of nerve physiology that reflex contractions are more resistant to psychogenic disorders than are the conscious and voluntary actions In hysterical aphonia, for example, the cough reflex remains normal, while voluntary phonation is lost Similarly, the functional form of open rhinolalia is differentiated from organic palatal paralysis by the preservation of the palatal gag reflex in the former This fact can be utilized for better tubal inflation

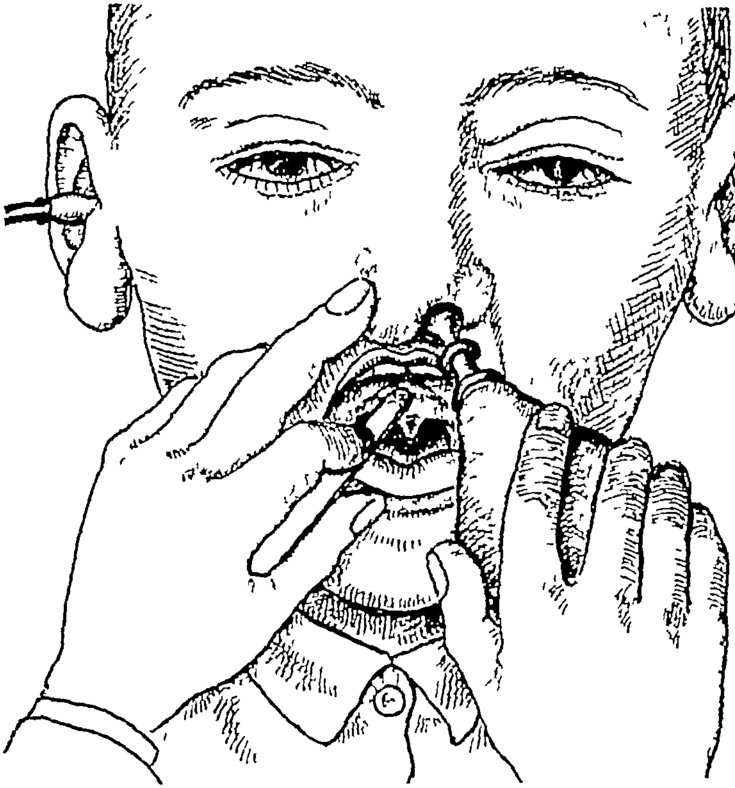

Fig 2 Inflation during reflex innervation of palate

As Fig 2 shows, a tongue depressor is held gently against

TRANSITIONAL CELL TYPE SQUAMOUS CELL CARCINOMA OF THE EXTERNAL EAR CANAL *

YOGINDER N MEHRA, M B B S ,

Montreal, Canada

The case of this 65-year-old female is being reported because of an uncommon type of lesion in the external ear canal

At the age of five years she had scarlet fever and both ears discharged Following this illness she had intermittent discharge from the right ear for a period of ten years She had no further evidence of ear infection until 1957 when following a cold the right ear began to discharge again Local treatment gave no relief The discharge persisted and occasionally was blood tinged

At the time of admission to this hospital in September 1957 she gave no history of headache dizziness or pain in the ear The nose accessory nasal sinuses pharynx and larynx were normal A general physical examination including X rays of the chest elicited no abnormalities

It was noted that her left ear drum was normal the right ear canal was filled with a large polyp and some discharge The fistula test was negative The regional lymph nodes were not palpable

X rays of the mastoids including tomograms showed suggestive evidence of some minimal enlargement of the mastoid antrum as if by a cholesteatoma There was no evidence of active bone destruction at the inner end of the external ear canal

Under local anesthesia with 2 per cent xylocaine infiltration the polyp in the right ear canal was removed The details of the drum and middle ear could not be made out The bleeding was not excessive Part of the tissue removed was sent to Pathology and part to Bacteriology departments for examination Bacteriology reported only micrococcal growth

Following the removal of the polyp from the right ear vestibular tests were normal in each ear The hearing tests showed the left ear to be normal On the right side there was an average loss of 25 db in the speech range in keeping with a mixed conductive and perceptive deafness

In view of the pathological diagnosis of transitional cell type carcinoma (see Fig 1) the case was discussed with the radiotherapist the radiologist and the pathologist and it was decided that radical excision should be attempted followed by radiation therapy

A radical mastoidectomy through combined endaural and postauricular approaches was carried out on Sept 28 1957 The mastoid cells and the middle ear were found to be free from obvious infection and definitely free from growth The ear drum though much thickened and scarred appeared to be intact when it was removed together with ossicles The growth and ulceration appeared to be limited to the skin of the inner

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*Departments of Otolaryngology and Pathology Royal Victoria Hospital Montreal Canada.

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so that inflation may be performed without haste, *3* It is easier for a patient to say a long "sss" than to pronounce "kay-kay-kay" at a precise instant

Disadvantages Cannot be used in the very rare case of nasal lisp, a speech disorder due to relaxation of the palate during the articulation of the S-sounds

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THE COLLEGE OF MEDICAL EVANGELISTS

A course in "Reconstructive Surgery of the Septum and External Nasal Pyramid" will be sponsored by the Departments of Otolaryngology of the College of Medical Evangelists School of Medicine and the University of Southern California School of Medicine, and will be given at White Memorial Hospital, Los Angeles, Calif The course will begin at 7 00 P M, January 6, 1959, and end 12 00 noon Friday, January 16 Dr Maurice Cottle will be the director All applications should be forwarded to Leland R House, M D, 1720 Brooklyn Avenue, Los Angeles 33, Calif is undoubtedly rare, although a considerable number of cases have been recorded in the literature, and lately increasing numbers are being reported

Most of the published reports show squamous cell carcinoma to be the most common of all types Other types, like the basal cell carcinoma, adenocarcinoma, adnexal carcinoma from the sweat and apocrine glands, the lympho-epithelioma, and the transitional cell type carcinoma, have also been reported

Different proportions have been given in different reports Spencer[8] (1938) describes seven cases of carcinoma, out of which six were squamous cell, and one basal cell type

Figi and Hampstead[4] (1943), describing malignant tumors of the middle ear and mastoid, report 38 cases, of which 13 are squamous carcinoma, 11 basal cell carcinoma, five adenocarcinoma, three sarcoma and six hemangio-endothelioma

Lindahl[6] (1955), reported 16 cases of carcinoma of middle ear and meatus, of which 13 are squamous carcinoma (both poorly differentiated and well differentiated), one adenocarcinoma, one carcinoma-like lympho-epithelioma, one transitional cell carcinoma

Ellis and Pracy[3] (1954) have published six cases with only one well differentiated squamous carcinoma

Gisselsson[5] (1952) describes a case of squamous cell carcinoma of the tympanic membrane

Ash[1] (1956) stated that most cases of adnexal carcinoma are usually diagnosed as adenocarcinoma

Cancer may originate in the external auditory meatus or middle ear, and it is sometimes difficult to know the exact site of origin, although prognostically it is very significant According to Miller[7] (1952), cancer of the auricle located within 1 cm of external auditory meatus is a serious disease, regardless of the histological description He recommends wide excision for carcinoma of external auditory meatus

Wahl et al[9] (1953) classify new growths of the ear as third of the external canal especially of the floor and of the anterior wall The whole inner four-fifths of the skin of the ear canal was removed The underlying bone was scraped There was no sign of the growth invading or being connected with the middle ear The denuded cavities were covered with skin grafts from the thigh

Histopathological examination of over 20 pieces of tissue removed from the different parts of the mastoid, the middle ear and the external ear revealed that the growth was confined to the skin of the inner half of the anterior wall of the external auditory canal The drum itself was free from evidence of growth

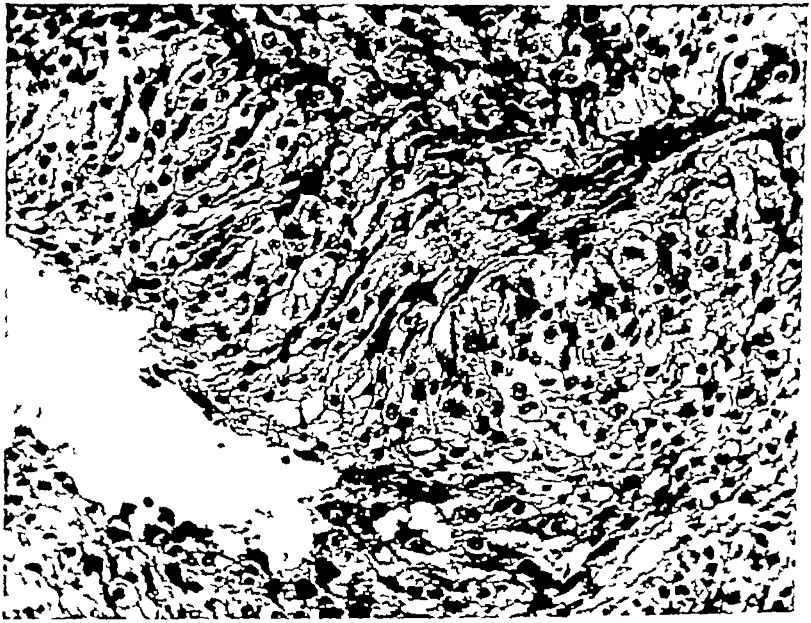

Fig 1 Transitional cell type carcinoma

The wound healed satisfactorily Radiation treatment was started on Oct 7, 1957 the ninth postoperative day and was terminated on Dec 13 1957 For the first six weeks, X ray therapy was given reaching a dose of 3120 *r* for the center of the petrous pyramid and the middle ear and skin dose of over 4600 *r* to anterior and posterior fields There was some skin reaction The graft had taken well Further treatment was given with Cobalt 60 using a direct lateral field An overall maximum tumor dose of 6045 *r* was reached

The patient was discharged on Dec 16, 1957 At the time of discharge the lining of the middle ear and mastoid cavities showed some erythema and moisture but no sign of growth or ulceration There was no cervical lymph node enlargement

Carcinoma of the middle ear and external auditory canal as transitional cell carcinoma, however, it also showed some areas in which the transitional character of the tumor became more differentiated and showed squamous features (see Fig 2)

The transitional cell type of squamous cell tumor is one of the undifferentiated types, morphologically Histologically, it resembles a carcinoma of the urinary tract. The cells have oval, elongated and fairly concentrated nuclei with a relatively small amount of cytoplasm, and have not differentiated into either frankly columnar cells or prickle cells

This tumor has a typical arrangement of cells in ribbon-like sheets that are looped and folded It commonly arises from mucous surfaces, but in the present case there was no evidence that it arose from the mucous surface of the middle ear It arose from the skin of the external canal, which is rather unusual Most pathologists would probably diagnose this as an undifferentiated type

The case reported by Lindahl[6] is the only similar one which could be found

SUMMARY

A case is reported of transitional cell type of squamous cell carcinoma of the external ear canal without involvement of the middle ear

A 65-year-old woman had had ear discharge during youth, which recurred during the past year and was occasionally blood-tinged Widespread excision of the growth and radical mastoidectomy was followed by radiation therapy

I express my thanks to Dr W J McNally, Dr E A Stuart and Dr G C McMillan for their help in the preparation of this report

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1 Extrinsic, in which the auricle, concha, or the external ear canal is involved

2 Intrinsic, which involves the tympanic membrane, tympanic cavity or mastoid process

3 Undetermined, origin of which cannot be accurately ascertained

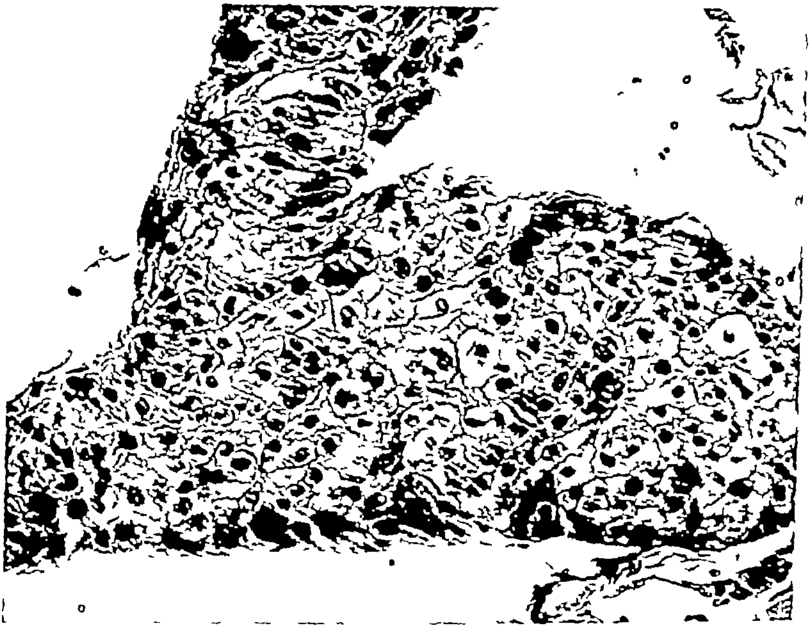

Fig 2 Squamous character of the tumor

The malignant neoplasm in the tympanic cavity probably results from a metaplasia of cylindrical cells of the lining membrane to the squamous cell type, or it may have its origin from the glandular elements within the cavity

The origin of carcinoma in this case was thought to be from the middle ear because of the long history of otitis media, however, at operation, and histopathologically this presumption was found to be incorrect The tumor involved the deeper part of the external canal without involving the drum or the middle ear cavity It was diagnosed initially

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RHINOMANOMETRY IN SOME RHINOLOGIC DISEASES

JOSEPH H OGURA, M D ,*
and
POUL STOKSTEAD, M D †
St Louis, Mo

The function of the nasal passages during respiration can be determined by rhinomanometry, a method of measuring pressure variations within the nasal cavity Courtade[1] described pressure variations obtained from the right and left nostril by means of a simple U-shaped water manometer attached to a nasal plug His method gave a very rough idea about the passages of the nasal cavities since his liquid manometer was capable of indicating only the maximum and minimum pressure in the rhinopharynx The disadvantage of his method was that values obtained were dependent upon the respiration rate and provided no possibility of estimating the pressure during respiration through both nasal cavities

The great advantage of the Courtade method was the use of simple equipment and easy applicability to the patient One of us (P S [2]) has improved the method by replacing the liquid manometer with a recording diaphragm-type manometer that is capable of integrating as well as recording the pressure variations during each phase of respiration The manometer

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*Department of Otolaryngology Washington University School of Medicine St Louis Mo

†From the Department of Ear Nose and Throat Disease University of Copenhagen Denmark (Chief Prof H K Kristensen M D) Visiting Fellow in Otolaryngology Washington University School of Medicine St Louis Mo

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is connected with an amplifying unit provided with two ratemeters, which add up the inspiration and expiration pressures respectively The ratemeters are monitored by a timer which starts and stops the ratemeters at a previously stipulated time of one minute A recorder which registers the pressure curves and the respiratory rate per minute is attached to the rhinomanometer

From the recorded values it is possible to calculate the resistance during inspiration and expiration through the right and left nasal cavity and by means of a formula to calculate the total resistance of the nose during free respiration through both nasal cavities

Long practice has demonstrated that it is most convenient to measure the resistance in the right and left nasal cavities at intervals of half an hour, and to follow the deflections of the resistance for a period of 45 minutes To give a comprehensive view of the mutual proportions between the resistance of the right and left side together with the total resistance, the obtained values are plotted in a coordinate system in which the time is plotted along the abscissa and the resistance along the ordinate

In the last two years we have been able to make about 350 tests from normal persons and from patients suffering from various nasal diseases Fairly good impressions of the normal rhinometrical curves and curves typical for the nasal diseases in question have been obtained Unfortunately, most people will have more or less deviated septa or asymmetrical development of the turbinates This will result in obtaining curves of a mixed type

THE NORMAL NOSE

The ideal nose has a relatively uniform calibrated slit-shaped nasal cavity, ½-mm wide at its narrowest point with the septum The regular alternating movements of the turbinates adjust in such a way that the total lumen or resistance during the inspiration and expiration is kept at a constant level Few normal noses will comply with the mentioned demands due to deviations of the septum, spurs and cristae

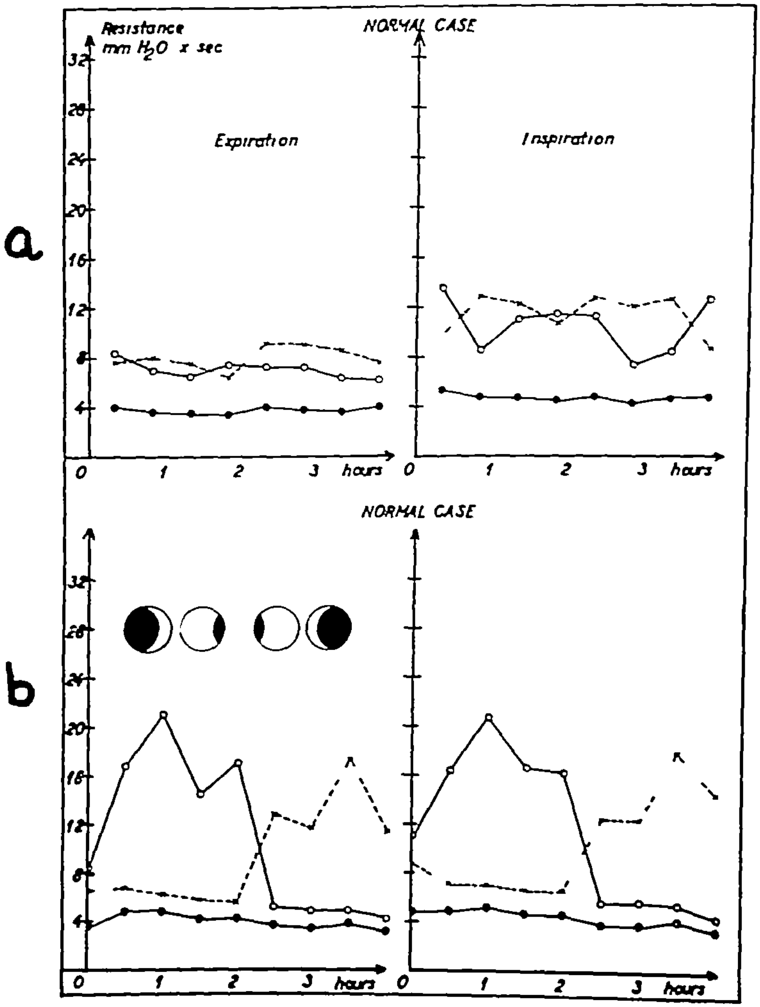


Fig 1 Inspiration and expiration curves from two normal persons with normal deflections of the turbinates and normal resistance in the nasal cavities o - o - o - o Resistance in the right nasal cavity x - x - x - x Resistance in the left nasal cavity ● - ● - ● - ● Calculated resistance of the entire nose (Total resistance)

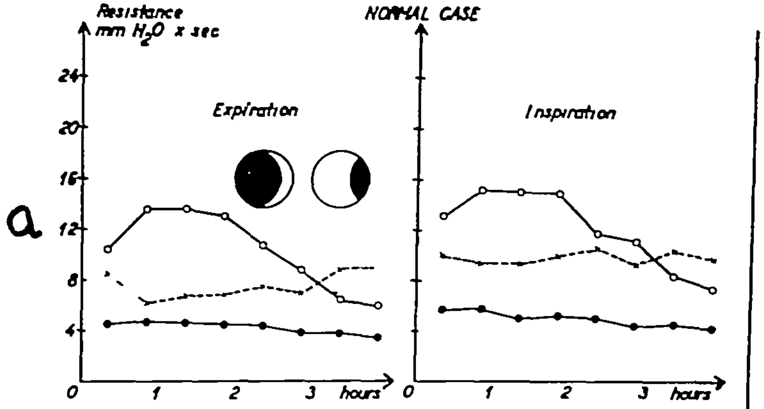
The curves in Fig 1-a are from a person with very high and narrow nasal cavities while Fig 1-b shows curves from a person with ample space in the cavities and large prominent turbinates The black moons indicate the engorgement of the turbinates with corresponding narrowing of the airway and the associated open airway on the opposite side of the nose with constricted turbinates when one considers these anatomical deformities with irregular development of the turbinates The curves shown in Fig 1-a are, however, approaching the "normal" circumstances The curves are obtained from a normal person with high and narrow nasal cavities The deflections of the turbinates are fairly small and the curves from the right and left nasal cavity intersect irregularly due to a slight contraction of the left side

Fig 1-b shows curves from a person with a broad, low nose with large prominent turbinates in the nasal cavities The movements of the turbinates are very pronounced and alternate in such a way that the total resistance in the nose is kept on an almost constant level At the beginning of the curves the turbinates on the right side are constricted but increase rapidly to the peak of dilation and reach the next phase of contraction in two and one-half hours, while the left turbinates undertake the opposite movements According to Heetderks[3] these movements are called the physiologic cycle of the nose, and the purpose of this cycle is to moisten and heat the respiratory air and prevent drying and cooling of the mucous membranes in the lower respiratory passages Warming of the respiratory air occurs mainly in the contracted nasal cavity, where the turbinates are dilated owing to the copious blood supply On the opposite side the turbinates are contracting and throwing off thin secretion from the serous glands and in this way create a situation for adequate evaporation

The length of the nasal cycle is measured between two similar phases of the movements of the turbinates and has an average duration of two and one-half hours, but in normal cases usually show variations between one and five hours

COMPENSATORY HYPERTROPHY OF THE TURBINATES

In instances where significant differences between the lumina on the right and left side exist, the turbinates in the wider side will hypertrophy for the purpose of filling this cavity This hypertrophy is usually explained as the effort of the body to compensate for this deformity Fig 2 illustrates such a case, where the left nasal cavity is considerably



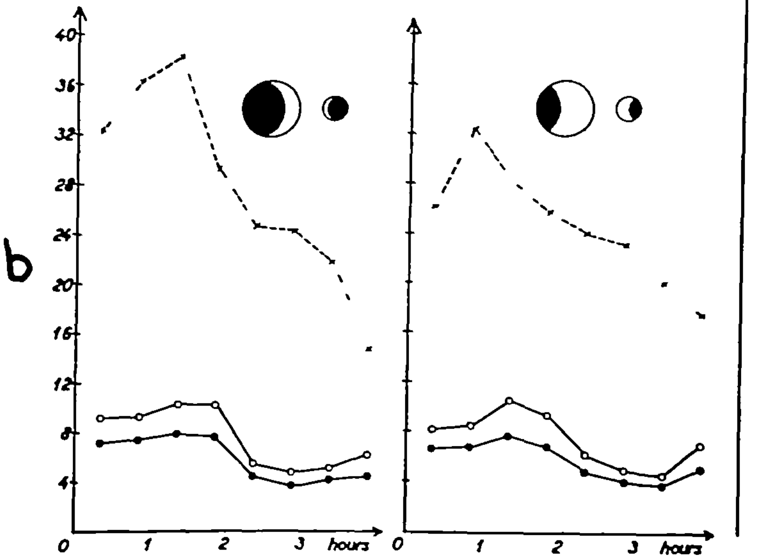


Fig 2-a Rhinometric curves from a person with normal alternating movements of the turbinates

Fig 2-b Inspiration and expiration curves from a patient showing pronounced contraction of the left nasal cavity and with ample space and hypertrophy of the turbinates on the right side The movements of the turbinates are synchronous

contracted, while the right side has ample space and large prominent turbinates The left side is narrowed to such a degree that it contributes only slightly to the air passage, and the right nasal cavity is the main conductor of the air current during respiration For this reason the resistance curve from the right side and from the entire nose will show parallel courses rising and falling according to the movements of the right turbinates In several instances the turbinates showed synchronous instead of alternating movements, which accelerate the fluctuations of the resistance curves

Patients of this category will usually complain of stuffiness in the wider side of the nose Diagnostic errors can be easily made, for inspection of the wider nasal cavity usually reveals that the turbinates are small and appear shrunken

DEVIATION OF THE NASAL SEPTUM

The most frequent cause of alteration in the rhinometric curves are deviations of the nasal septum Generally, one side will show an almost normal space and normal cyclic curve, but the contracted nasal cavity will show pronounced irregularities caused by contact of the turbinates against the septum during a part of the dilating phase Fig 3-a shows a case of a marked septum deviation with the spine and septum projecting into the left nostril During the dilatation of the turbinates the left side is almost shut off, but during the contraction phase the nasal cavity will open suddenly resulting in a short period of decreasing resistance In the case shown, the total resistance is so high that the patient has to undergo reconstruction of the septum for the purpose of re-establishing a normal airway

VASOMOTOR RHINITIS

By rhinometric examination of a normal nose with the surrounding atmosphere kept at a constant temperature and humidity, we have observed alternating movements of the turbinates On one side of the nose the turbinates contract and throw off thin secretion from the serous glands, while the turbinates on the other side dilate with engorgement of the vascular system for the purpose of heating the inspiratory

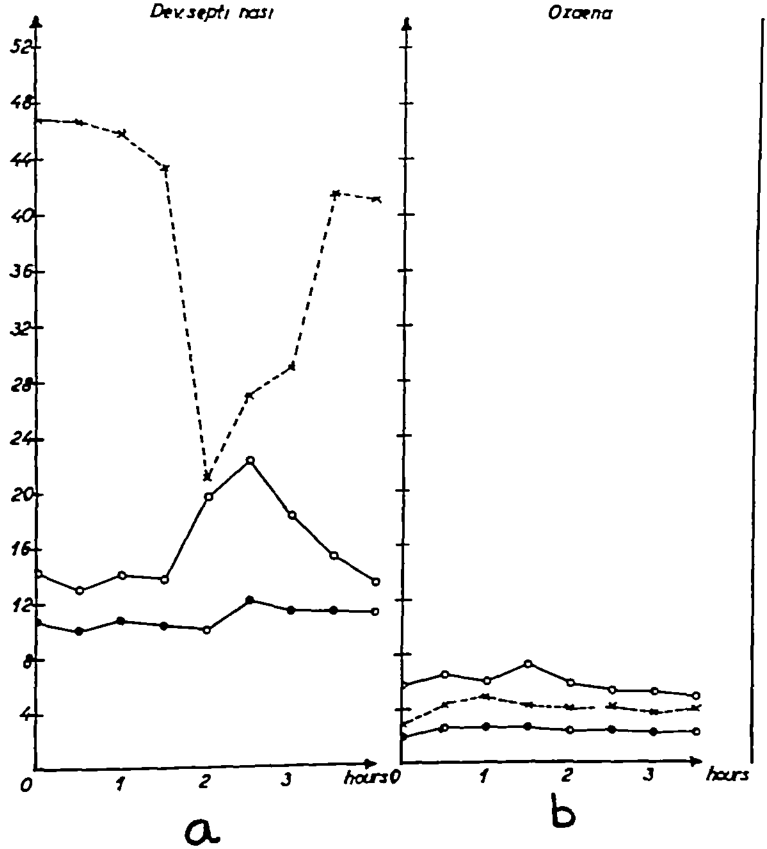


Fig 3 Resistance curves during expiration from a patient with septum deviation to the left (3-a) and from a patient suffering from ozena (3-b)

air current The movements are connected with alternating changes in the lumina of the nasal cavities in such a way that the computed lumen of the nose is kept at the same level

Physical factors such as variations of temperature and humidity cause the turbinates to respond with synchronous movements and contract or dilate at the same time in both nasal cavities in order to prepare the air for the lung[3] The deflections caused by the synchronous movements are generally so pronounced that they almost cover the alternating movements, which will first appear again when the nasal cavities have accomplished their adaptation to the new atmosphere

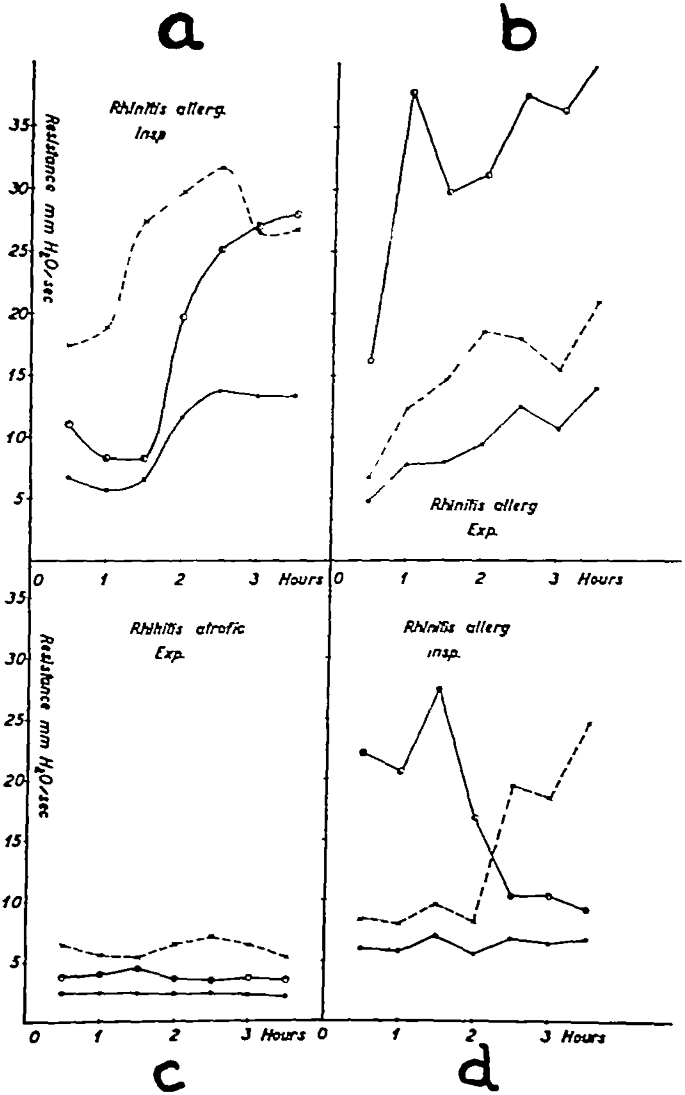
In a normal nose the changes elicited in the vascular system by changes of the temperature and humidity will be kept within such limits that there remains sufficient space for adequate respiration, but in vasomotor rhinitis the reactions are exaggerated, and the responses arise even with abnormally small variations in the atmospheric condition Furthermore, the engorged phase of the turbinates is maintained over abnormally long periods, causing stuffiness of the nose and an accumulation of secretion in the glands of the turbinates, resulting in a profuse thin secretion from the nostrils when the turbinates reach the stage of relaxation

Typical curves are shown in Figs 4-a and 4-b in patients with vasomotor and allergic rhinitis The resistance curves from right and left nasal cavity start at normal level, but after a short period of time the turbinates respond to the temperature and humidity of the laboratory, which results in a steady increase in resistance on both sides, and breathing difficulty for the patient

In a few cases we have seen another curve as shown in Fig 4-d with exaggeration of the alternating deflections of the turbinates, and sometimes with acceleration of the nasal cycle We are inclined to believe that this is a variant of vasomotor rhinitis, but the investigations so far are not conclusive

OZENA AND ATROPHIC RHINITIS

Before testing the patients suffering from ozena it has been necessary to remove crusts from the nasal cavities with irrigations of saline solutions Crusts obtained from ozena patients are identical with the diagram shown in Fig 4-c, with extreme low values indicating complete lack of movement of the turbinates Extensive chronic inflammation and atrophy of the turbinates have affected their ability to influence the air currents during inspiration and expiration In a few instances normal or slightly increased resistances are observed in one or both cavities due to a narrowing of the internal *os*,



Figs 4-a and 4 b Rhinometric curves of patients with vasomotor rhinitis The abrupt rise in the resistance are caused by synchronous movements of the turbinates

Fig 4-c Atrophic rhinitis with very small deflections of the turbinates and a diminutive cycle of the nose

Fig 4-d Vasomotor rhinitis with exaggeration of the alternating movements of the turbinates

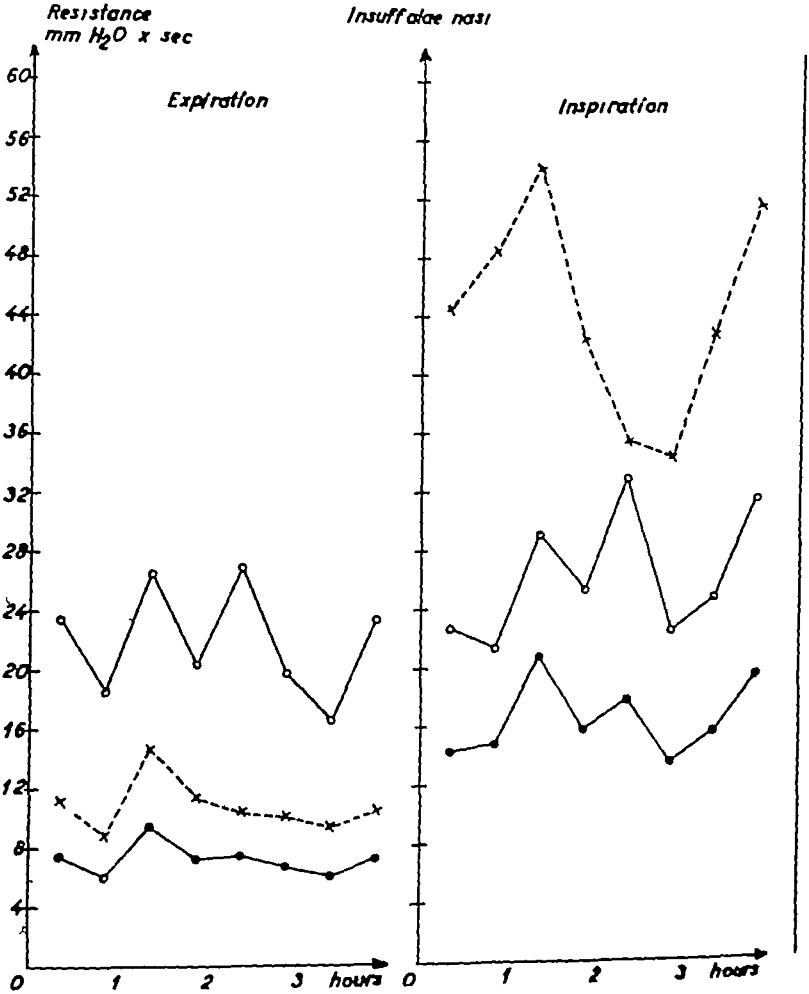


Fig 5 Rhinometric curves during inspiration and expiration in a case of collapsing alae nasi The obstruction is most pronounced on the left side which has normal resistance during expiration but a pronounced increase of resistance during inspiration

that portion between the vestibule and the nasal cavity proper, despite the atrophy and reduced excursion of the turbinates With such small and low pressure deflections in atrophic rhinitis it is almost possible to identify the movements of the turbinates and a diminished cycle of the nose

In a normal patient the turbinates will show a very pronounced engorgement, resulting in complete obstruction of the nasal cavity in question if the stellate ganglion is blocked, however, in atrophic rhinitis since the vascularity is reduced there is a very incomplete response to the stellate ganglion block, and the dilation will disappear much faster than in normal cases

COLLAPSING NASAL ALAE

During each moderate respiration the nasal alae move outwards like a pair of floodgates,[4] thereby dilating the internal *os* and reducing the resistance during the inspiration phase to such an extent that both respiration phases are kept at almost the same resistance level, despite the fact that the inspiration phase lasts a somewhat shorter time than the expiration The movements of the alae are controlled by the levator alae muscles and increase in magnitude by forced respiration The contractions of the muscles occur just before the inspiration begins and continue during the whole inspiratory phase, while the muscles relax during the expiration The activity of the muscles was demonstrated by Van Dishoeck,[5] who was able to detect action potentials from the muscles The movements depend upon a reflex arc, which has its efferent pathway via the facial nerve

Collapsing nasal alae are observed in patients with high, long and narrow noses, and is due to the disturbed anatomical relationship of the upper lateral and alar cartilages to the septum, and in some instances with paralysis of the facial nerve The high and elongated septum is associated with the narrowing of the caudal end of the upper lateral cartilage relationship to the septum This effectively reduces the size of the internal *os* and collapses the nasal alae upon moderate forced inspiration

Usually there are differences in the degree of insufficiency of the nasal alae on the two sides, and this must be considered in naasl reconstruction for the purpose of obtaining satisfactory ventilation of both nasal cavities

RELATIONS BETWEEN THE NOSE AND LUNGS

Recently we have tried to establish a relationship between the nose and the lung Few studies have been made on efforts to measure pulmonary function together with the nose In this respiratory test, one measures the ability of the lung to expire through the nose against a calibrated resistance An inflatable rubber mask is fixed tightly to the head by means of rubber ribbons and is provided with a calibrated valve[2] In beginning the test, the diaphragm of the valve is adjusted to an opening that does not interfere with the respiration of the patient The valve is later closed in steps, at five minute intervals up to the valve opening, which allows the patient just a sufficient supply of air The respiratory resistances arising in the mask during the test are measured by the rhinomanometer unit and the respiration rates are registered at every step by which the valve is closed

Most normal people are able to breathe against a resistance ranging from 80 to 100 mm H_2O x sec, which is about 20 to 25 times as much as the normal resistance of the nose In some apparently normal cases we have seen much lower values, which is in conformance with the investigation of McKillick,[5] who found 20 to 30 per cent of lowered pulmonary function among normal persons

In a few mouth-breathing patients with this respiratory test, we have been able to detect very low resistance values, due to a decreased ability of the lungs to respirate against the normal resistance of the nose Many of these cases have shown, at the same time, decreased nasal resistance with an almost normal proportion between this respiratory test and nasal airways For this reason these patients have maintained their normal respiration through the nose

DISCUSSION

Much information has been obtained about the configuration of curves typical in normal patients and in certain nasal diseases We have obtained typical curves in cases of vasomotor rhinitis, septum deflections and collapse of the nasal alae, and we have been able to determine the degree of each factor involved Obviously this is of importance from the therapeutic point of view A correction of the septum, the abolition of the collapsing nasal alae would be of value to the patient when the vasomotor component is not too pronounced The exaggeration of the alternating movements of the turbinates and the acceleration of the nasal cycle will be evident in vasomotor rhinitis

In other cases we have found a normal nasal airway despite the severe complaints of nasal discomfort Most of those instances are cases of nasal neurosis, or possibly an undetected pulmonary or cardiac disease of short duration In both instances surgical intervention is not advised Surgery would not be advised, even though obvious anatomical deformity was present In the former instance the complaints of the patient will usually increase if surgery is performed Often nasal complaints will disappear after appropriate treatment for pulmonary or cardiac disease

The measurement of the ability of the patient to breathe against resistance, as measured through the nose is a respiratory test, but may not represent a true pulmonary function test Many variables enter into this picture The muscular strength of the chest wall, general condition of the patient, bronchial resistance, volume exchange, elasticity—the problem of lung compliance—which is not measured in this instance The real importance of measuring the pulmonary function in connection with the rhinometric test of the nasal cavities was emphasized by Sercer[6] several years ago, but it has to some extent been neglected by later investigators It is significant that to date no definite relationship of the nose and the lung has been established by an objective test Nasal function test, as measured by the rhinomanometer, and the establishment of pulmonary function tests are well documented by simultaneous observations of both present major technical problems

Clinically it is important to know whether this relationship exists Why is it that some people with obstructive nasal airways, due to a badly traumatized nose, complain of dyspnea? The "chronic lunger" who bitterly complains about nasal obstruction, the chronic mouth breathing child often has a deformity of the chest with a pronounced flattening of the ribs One wonders about this relationship! The adult patient with oral respiration may have decreased ability to breathe against resistance In such instances, it seems that attention should be directed toward improving the nasal airway surgically, and perhaps even toward proper pulmonary exercises

Since the nose serves as a protective organ and prepares the air for the lung, it seems logical that we should look for better objective methods for testing nasal and pulmonary functions

SUMMARY

On the basis of about 350 rhinometric examinations of the nasal passage with resistance measuring from the right and left nasal cavity, typical resistance curves are shown from normal persons and from patients with deviations of the septum, vasomotor rhinitis, and atrophic rhinitis with ozena and collapse of the nasal alae

The relationship between the nose and lung is discussed briefly A method is outlined for measuring the ability of the lung to breathe against increasing resistance

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A STUDY OF THE RELATIONSHIP OF AIR PRESSURE TO MYRINGORUPTURE *†‡

A PAUL KELLER, JR , M D ,

Athens, Ga

The aim of this study was to determine what amount of air pressure, within a closed system, directed against the human tympanic membrane would cause it to rupture

In 1898 Lester and Gomez[33] reported the effects of compressed air on the human ear from observations made in a caisson of New East River bridge The study was mainly concerned with the effect on hearing, but several conclusions have a bearing on this study For example, it was stated that the hearing power for both air and bone conduction was reduced directly in proportion to the atmospheric pressure, more specifically, it was pointed out that a pressure of one-half an atmosphere caused depression of the drum membrane, and a pressure of two atmospheres caused a marked disturbance of the drum membrane with congestion of the pars flaccida and the malleolar plexus, and that when descending in the caisson, there was considerable danger of the drum membrane's rupturing unless the Eustachian tube was successfully opened voluntarily They warned against persons with colds, chronic ear disease or labyrinthine disease entering a caisson

In 1929 Vail[40] gave a report to the American Otological Society concerning traumatic ear conditions in workers under compressed air His work was mainly concerned with caisson disease and its effects on the middle and inner ears He reported two cases of rupture of the human eardrum membrane, one in a Negro man while working under a pressure of 27 lbs /in^2 and the other a "young" man working under a

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*Submitted as Candidate's Thesis to American Laryngological Rhinological and Otological Society Inc 1957

†The assistance of Dr A V Gafford Rome Ga in performing the tests and of Associate Professor R Gilbert Henry Physics Dept. University of Georgia in deriving the formulation is hereby gratefully acknowledged

‡From the Dept of Otology and Rhinolaryngology Emory University

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pressure of 30 lbs/in.² How closely these figures approximate those found from this study will be apparent soon.

In 1937 Armstrong and Heim[3] reported the effects of positive and negative pressure on the eardrum membrane of five apparently healthy men. They found that as atmospheric pressure decreased (as in an ascending airplane) the Eustachian tube opened automatically, first, when the pressure differential reached 15 mm. of mercury, next, when it reached 11.4 mm., until at 40,000 feet it opened at a differential of only 3.5 mm. This they attributed to a rarefaction of the air, which then passed through the Eustachian tube more easily; however, when the atmospheric pressure increased (as on the descent of an airplane) the Eustachian tube failed to open spontaneously and remained closed at all pressures unless voluntarily opened. At a differential of 60 mm. of mercury of negative pressure, pain became severe, at 60-80 mm. very severe, and at more than 80 mm. agonizing. They stated that the eardrum membrane ruptures between 100 and 500 mm. of mercury, and reported one case that ruptured at 470 mm. of mercury accompanied by a loud report, shock and severe dizziness. (It was not revealed how the figures of 100 to 500 mm. of mercury were derived, nor how many eardrum membranes were ruptured.) It was noted that when a negative pressure differential of 80 to 90 mm. of mercury developed, the muscles of the Eustachian tube could no longer voluntarily open the tube.

In 1941 Van Dishoeck[17] studied tension on the human tympanic membrane in relation to hearing and decided that any deviation from the normal tension led to hearing impairment. He used pressures up to 100 cm. of water without any reported rupture. Canfield[6] in 1944 reported results of pressure chamber experiments on the tympanic membrane, *e.g.*, decompression from 7,000 feet (equivalents), and found severe retraction and aerotitis, which readily responded to myringopuncture, but he did not mention any spontaneous ruptures.

In 1942, and again in 1945, there appeared articles by H. B. Perlman[40,41] of Chicago concerning the effect of explosion and blast on the human acoustic conduction apparatus. By attaching tiny mirrors to various parts of the conduction apparatus in fresh, human, temporal bones he was able to measure the displacement of the part under study (*e g* , malleus or stapes) and record its excursions under the influence of the shock pulse produced by explosions or loud sounds He discovered that at a magnification of 200 times the malleus moves when stimulated by a sound at 50 db above the threshold of hearing It was mentioned in these papers that static pressure of 200 to 400 mm of mercury would rupture the tympanic membrane, but how these figures were determined was not elucidated Several other figures regarding the pressure developed by the shock pulse were mentioned Since the threshold of sound perception at 1000 cycles is 10^{-16} watts/cm ^{2} it can be seen that the intensity of the shock pulse is usually many times greater than the "loudest sustained sounds" and may equal many atmospheres For example, Perlman points out that Thompson measured the intensity of the shock pulse 26 feet from the explosion of 10 lbs of TNT and arrived at a figure of 10^4 watts/cm ^{2} which is equal to 200 db above the threshold of sound perception He quotes Miller as stating that the pressure developed 12 feet in front of a 12-inch gun is 542 lbs /in ^{2} Sustained sound becomes unbearably loud at about 10^{-4} watts/cm ^{2} (or 120 db), so it is easy to see how greatly shock pulses exceed the usual decibel intensity of sustained periodic sound Craig[11] stated that probably the first case of traumatic perforation of a tympanic membrane by explosion to be examined and visualized by otoscopy was that seen by Gruber in 1866, three weeks after the battle of Sadowa

In 1943 Dean[16] discussed blast injuries, and pointed out that a 70-pound charge created a pressure of 110 lbs /in ^{2} at 14 feet distance, 60 lbs /in ^{2} at 18 feet, 15 lbs /in ^{2} at 30 feet and 6 lbs /in ^{2} at 50 feet and that 100 lbs /in ^{2} is dangerous to life

The effect of aircraft noise upon hearing was reported in 1944 by Senturia,[46] who noted that noise levels of 128 db were reached in trainer planes and stated that this decibel intensity approaches pain level as well as causing auditory fatigue Also in 1944 Silov[47] reported on 82 cases of blast injury and noted that the loss of hearing was more severe when the tympanic membrane remained intact than when it ruptured Cantor[7] in 1945 sought to explain this observation on the basis that the pulse wave enters by way of the Eustachian tube, and if the tympanic membrane remains intact the middle ear acts as a pressure chamber transmitting force to the windows of the inner ear In 1945 Henry,[20] in discussing 292 blast injuries of the ear, failed to find any drum membranes perforated in Shrapnell's area

Fitz-Hugh[20] in 1946 discussed traumatic perforation in 58 servicemen due to high explosives, but did not suggest what pressure was exerted on the eardrum membrane Ireland[28] tabulated 317 cases of traumatic perforation from blast injury and concluded that high explosive and mortar fire was most often implicated, but the pressure necessary to rupture the eardrum membrane was not discussed In 1949 McReynolds[42] was able to report on 286 ears subjected to blast injury in the Texas City disaster but no mention of rupture pressure was made Whittingham[52] in 1954 discussed an unusual case of perforation of both eardrum membranes during anesthesia, when the patient was "hand breathed" with the bag, but the pressure exerted was not suggested and would be hard to predict Schnurbusch[45] in 1954 described a case of unilateral perforation of the tympanic membrane in a 30-year-old construction worker who was hammering on a tin cylinder and attributed the rupture to sound trauma There was a perforation anterior and posterior to the malleus handle associated with tinnitus and hearing loss Within three weeks the membrane healed, and the hearing returned to practically normal In the discussion of this case the author points out that the type of resistance offered to sound pressure by the tympanic membrane is varied At lower frequencies the drum membrane acts like an elastic membrane, whereas at higher frequencies, say about 800 cycles, it shows a resistance more like a mass reaction to the sound pressure Consequently, the elasticity of the drum membrane at low frequencies offers effective resistance, and considerable sound pressure is necessary to cause rupture At higher frequencies, due to the resistance of the drum membrane in mass, much less protection is offered, and higher frequency sounds can cause rupture with less pressure; however, higher frequency sounds are very directional, so the axis of the sound must be at right angles to the drum membrane to exert maximum effect. It can thus be seen that the main protective feature of the eardrum to low frequency sounds is its elasticity, while at higher frequencies the highly directional quality of the sound waves helps prevent sound trauma unless the axis is oriented at right angles to the drum membrane.

The lower frequency sounds would be expected to produce more bilateral perforations while the higher frequency, more directional sounds, would produce more unilateral perforations of the tympanic membrane.

A large number of discussions of blast injuries of the eardrum membranes appear in the literature, *e.g.*, Craig[11] in 1941, Alexander[1] in 1941, Dean,[16] Alexander,[2] Palmer[38] in 1943, Craig,[13] Silox,[47] Senturia[46] in 1944, Cantor,[7] Bennington,[5] Henry[26] in 1945, Korkis,[31] Ireland,[28] Fitz-Hugh[20] in 1946, Falbre[21] in 1947, Friedman,[23] Collins[10] in 1948, McReynolds,[42] Rice[43] in 1949, Garcia-Vaquero[24] in 1953; yet, insofar as it was possible to glean this material, no reference was found as to the pressure necessary to rupture the human eardrum membrane. Parenthetically, frequent reports have been made of perforations of the eardrum membrane associated with lightning injuries, and of sudden death due to drowning related to a perforation of the eardrum membrane. Obviously, these could not be concerned with pressure analyses.

Of the many available methods of rupturing the human eardrum membrane experimentally, the use of air pressure most nearly resembles the common manner in which many accidental ruptures occur, and so a method was devised whereby air under a measurable amount of pressure could be directed against the membrane in a closed system. Originally two 260 mm. sphygmomanometer tubes were sealed together, giving an effective pressure of 520 mm. of mercury, but this pressure failed to rupture either of the first two drum membranes tested. This method was discarded. Then, a hand-pumped air pressure tank was attached to a metal handpiece, with one pressure gauge at the tank and another

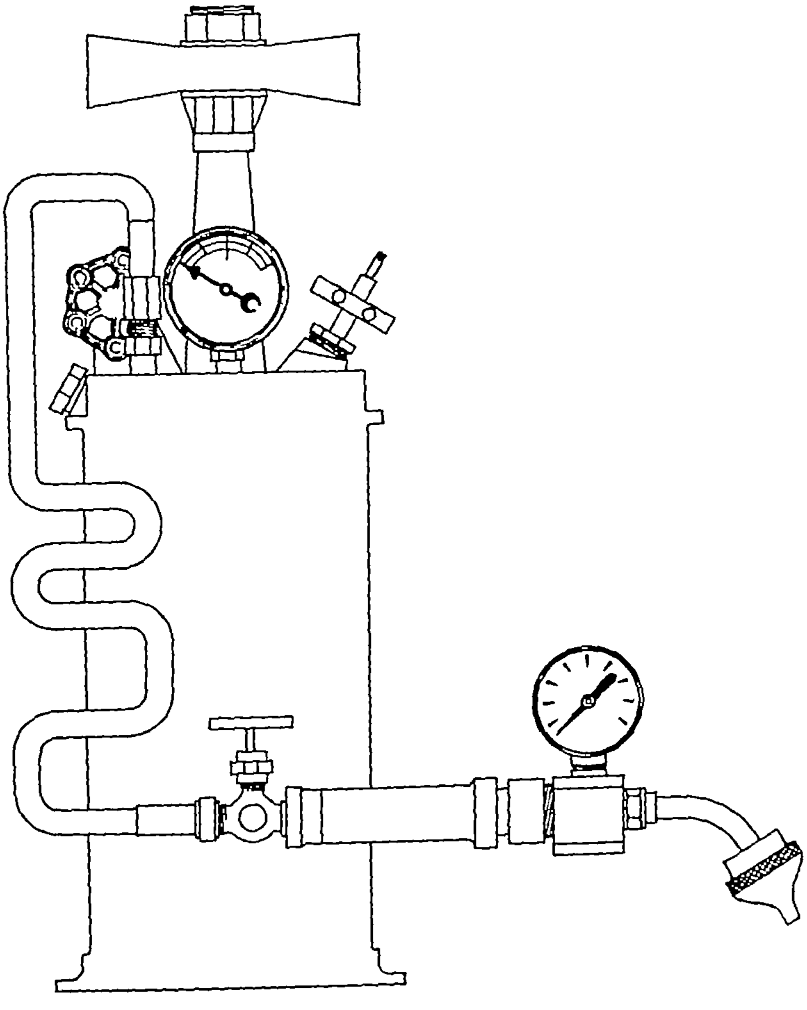

Fig 1 Drawing of Apparatus Utilized

at the hand piece, which was inserted into the external auditory canal A tightly fitting earpiece connected the pressure apparatus to the external auditory canal and transmitted the air pressure to the outer surface of the tympanic membrane (see Drawing) This was used for most of the work, but the hand-pump was later supplanted by a tank of compressed air, which was easier to transport and utilize

With such an apparatus air was directed against the outer

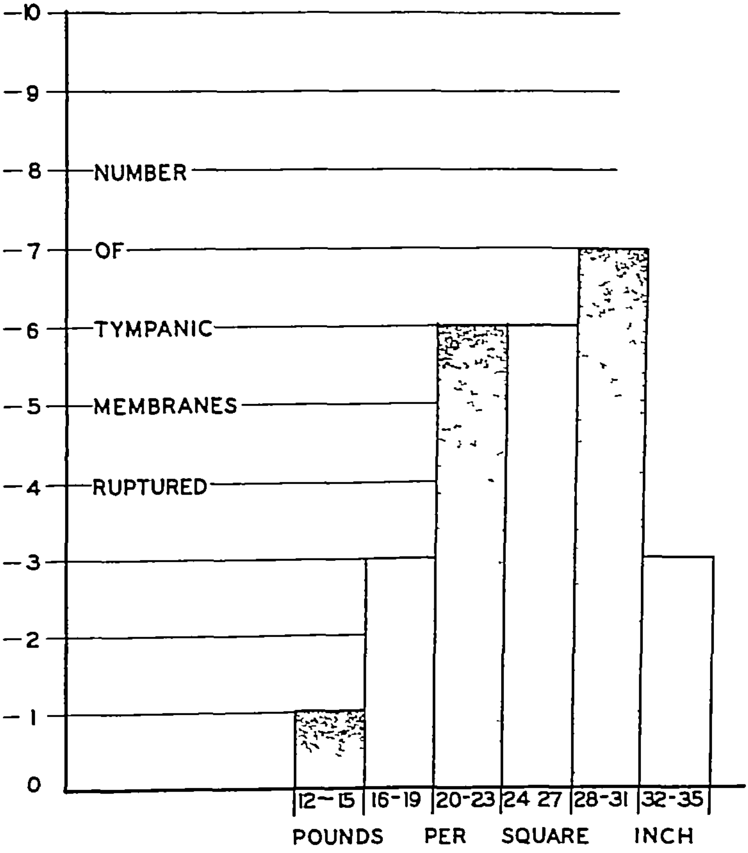

Chart 1

surface of the tympanic membrane of recently deceased human beings under a variety of conditions First, gradually increasing pressure was utilized until rupture occurred, then suddenly applied pressure was utilized, increasing the pressure with each application until rupture occurred, finally, in order to be sure that the pressure being measured was actually that required to rupture the eardrum membrane, and not also that necessary to open the Eustachian tube, the tegmen tympani was exposed and an opening made through this structure into the middle ear so that only the eardrum membrane opposed the air pressure

TABLE OF CASES

Age		Pressure (lbs /in ^{2})	Results	Location Point
51	AD	10	No perf	
	AS	10	No perf	
26	AD (S)*	28	Perf	Not visualized
	AS (S)	31	Perf	Ant inf pars tensa
28	AD (G)†	25	Perf	Ant to malleus handle
	AS (G)	20 5	Perf	Ant sup pars tensa
59	AD (G)	20	Perf	Ant sup pars tensa
	AS (S)	25	Perf	Post pars flaccida
49	AD (G)	21	Perf	Ant sup pars tensa
	AS (S)	23	Perf	Ant pars tensa
39	AD (G)	18	Perf	Post pars tensa.
	AS (G)	33	Perf	Ant inf pars tensa
50	AD (G)	40	No perf	Technical difficulty
	AS (G)	31	Perf	Pars flaccida.
25	AD (G)	33	Perf	Ant sup pars tensa
	AS (S)	26	Perf	Ant inf pars tensa
65	AD (S)	16	Perf	Post pars tensa
	AS (S)	14	Perf	Post. pars tensa.
Not Known	AD (G)	22	Perf	Post pars tensa
	AS (S)	20	Perf	Post pars tensa
Not Known	AD (G)	18	Perf	Ant pars tensa (tegmental opening)
	AS	Ruptured by instrumentation		
27	AD (S)	34	Perf	Ant. pars tensa
	AS (G)	30	Perf	Ant pars tensa (tegmental opening)
52	AD (G)	28	Perf	Post inf pars tensa
	AS (G)	30	Perf	Post inf pars tensa
83	AD (S)	24	Perf	Ant inf pars tensa
	AS (G)	30	Perf	Ant. inf pars tensa
2 Weeks	AD (G)	24	Perf	Ant inf pars tensa
	AS (G)	24	Perf	Not found

*Sudden †Gradual

The number of subjects tested was 15 The ages of the subjects at the time of death varied from two weeks to 83 years Four subjects were Negro, the remainder white Thirty eardrum membranes were examined by one of the above methods four did not rupture, either because of insufficient pressure (original attempts) or because of mechanical difficulties Of the eardrum membranes which did rupture the following observations were possible (see Chart 1) The lowest pressure at which any ruptured was 14 lbs /in ^{2} The highest pressure required to rupture any in the series was 33 lbs /in ^{2} The mean breaking pressure was 25 lbs /in ^{2} The right eardrum membranes ruptured at an average pressure of 24 lbs /in ^{2}, and the left eardrum membranes at an average pressure of 26 lbs /in ^{2} There was no significant difference between rupture pressures when gradual or sudden application was made Individual cases are presented with comments concerning each (see Table)

It is realized that the first question to be raised may be whether or not the eardrum membrane of a dead human being has the tensile strength of that of a live person In the living human being the stapedial and tensor tympani reflexes could act to protect the tympanic membrane, but it has been shown that the latent period of this reflex is such that it would not have time to act in blast injuries, as the pulse wave reaches its maximum in much too rapid a time interval Some of the ears tested were only slightly over two hours postmortem, and the longest time after death was 14½ hours There was no distinct relationship evident between length of time postmortem and the pressure necessary to rupture the eardrum membrane All subjects had been kept refrigerated until examined

All except two of the eardrum membranes which were ruptured showed tears in the pars tensa, the two exceptions occurring in the pars flaccida, 15 perforated in the anterior half of the pars tensa and eight in the posterior pars tensa In the two cases where the perforation could not be found, the pressure registered just prior to a sudden drop in pressure (accompanied by an audible escape of air through the Eustachian tube and nose) was recorded as the breaking pressure That there is a measurable loss of pressure between the gauge and the eardrum membrane is admitted, but is not considered significant in the gross measurements taken here, nor of clinical value because of the range of pressures in the series

After arriving at an average figure for the pressure at which a human eardrum might be expected to rupture, what then becomes of more import is the question of practical application of these figures Vail[49] has already reported that two different patients had ruptured eardrum membranes from positive pressures of 27 and 30 pounds per square inch respectively, and so the necessity of a caisson worker having functional Eustachian tubes (and voluntarily opening them)

FORMULATION

To Change lbs/in² to Decibels

Threshold of hearing = 10^{10} Microwatts/cm

Sound level in decibels 0

$$\text{Intensity} = \frac{\text{Power}}{\text{area}}$$

$$= \frac{\text{Force} \times \text{distance}}{\text{time}} \Big/ \text{Area}$$

10^7 dyne-cm or ergs = 1 joule

1 joule/sec = watt

$$\therefore \text{Watts/cm}^2 = \frac{\text{dyne}}{10^7} \quad \frac{(\text{cm})}{(\text{sec})} \Big/ \text{cm}^2$$

10^6 microwatts = 1 watt.

$$\therefore \text{Microwatts/cm}^2 = \frac{\text{dyne} \quad (\text{cm}) \times 10^6}{10^7 \quad (\text{sec}) \quad \text{cm}^2}$$

$$(\text{cm/sec} = \text{velocity}) \quad \frac{\text{dynes}}{10^7} \times \frac{\text{velocity} \times 10^6}{\text{cm}^2}$$

Velocity of sound = 33100 cm/sec at 0° C and increases 61 cm/sec for each 1° C rise above 0° C

$$\therefore \frac{\text{dynes}}{10} \times \left(\frac{33100 + (61 \times t^\circ\,\text{C})}{\text{cm}^2}\right)$$

$$\text{or } \frac{\text{dynes}}{\text{cm}^2} \times \left(\frac{33100 + (61 \times t^\circ\,\text{C})}{10}\right)$$

Acceleration of gravity = 980 cm/sec²

$$\text{dynes/cm}^2 = \text{lbs/in}^2 \times \frac{454 \times 980}{2\ 54 \times 2\ 54}$$

$$\text{lbs/in} \times \frac{454 \times 980}{2\ 54 \times 2\ 54} \times \frac{33100 + (61 \times t^\circ\,\text{C})}{10}$$

$$= \text{microwatts/cm}$$

$$\text{Decibels} = 10 \log \frac{E}{E^\circ}$$

$E^\circ = 10^{10}$ microwatts/cm² = Threshold of hearing

$$\text{Decibels} = 10 \log \left(\frac{\text{microwatts/cm}^2}{10^{10}}\right) = \text{Intensity}$$

$$10 \log \left(\frac{\dfrac{\text{lbs}}{\text{in}^2} \times \dfrac{454 \times 980}{2\ 54 \times 2\ 54} \times \dfrac{33100 + 61\ t^\circ\,\text{C}}{10}}{10^{10}}\right) = \text{Intensity in decibels}$$

Now in this formula $\frac{454 \times 980}{2\ 54 \times 2\ 54}$ = 68,980 or a constant of 69,000 and if the average temperature is assumed to be 30° C then $\frac{33{,}100 + 61 \times 30}{10}$ = 3,493 or as a constant 3 500 and the formula is reduced to

$$10 \log \left(\frac{\text{lbs/in} \times 241\ 000\ 000}{10^{10}}\right) \text{ or}$$

$$10 \log \quad \text{lbs/in} \times 241 \times 10^{14} = \text{Intensity in decibels}$$

is immediately apparent Similarly, Armstrong and Heim have indicated the practical value of this knowledge in aviation Numerous articles have indicated the relation of these figures to underwater diving, as in a recent review by Martins[36] Another phase is the relation of these pressure-rupture figures to sound Perlman[40] states (probably indirectly quoting Collier[9]) that if a 200-pound bomb exploded in State Street, Chicago, everyone on the street within a radius of 50 feet from the bomb would likely have ruptured eardrums

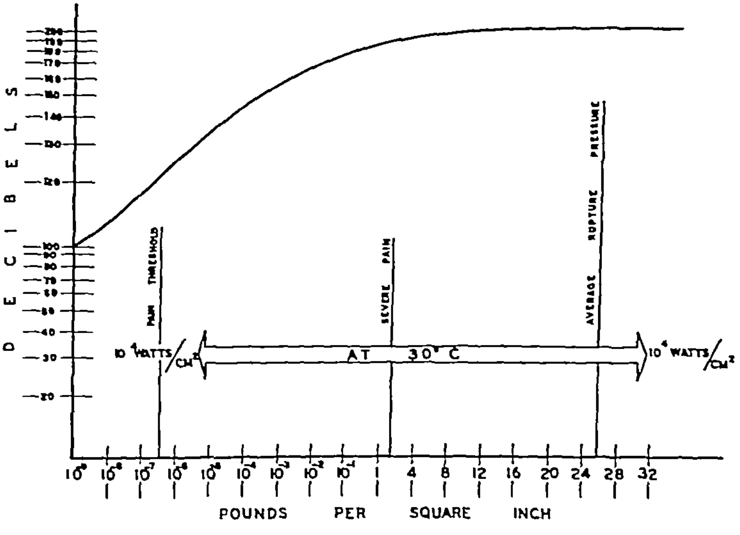

Chart 2

As the atom and hydrogen bombs and jet engines have opened new vistas in sound study, and a recent judicial verdict has made hearing loss due to acoustic trauma in industry compensable, it would seem well to know at what decibel intensity a human eardrum membrane might be expected to rupture It then becomes necessary to convert decibel intensity to pounds per square inch The earliest successful attempts to measure sound velocity in air were those of Marin Mersenne, a French physicist in 1640, and two Italian physicists, Borelli and Vivani, in 1656 One of the most recent, detailed and apparently accurate measurements of sound velocity was done by Miller[37] in 1934 The conversion of decibels (microwatts/cm^2) to lbs /in^2 is dependent upon two values being constant, namely velocity and temperature This is because the velocity of sound varies directly with the temperature and the variant between watts/cm^2 and lbs /in^2 is (flow) cm /sec (velocity) , therefore, in any description of lbs /in^2 in terms of decibels (watts/cm^2), it is necessary to state at what temperature the conversion is made, as this in turn would alter the velocity (see Formulation)

By substituting in the above formula it would seem that a human eardrum membrane may be expected to rupture at between 195 and 199 dbs at 30° C The threshold of pain, 120 dbs , is equal to 0000005 pounds per square inch, and if the figures of Armstrong and Heim are accepted, then very severe pain occurs at 186 dbs if the temperature be taken at 30° C (see Chart 2) It is felt that the system utilized in this study approximates that present in conditions resulting in *low frequency*, sonic, traumatic perforations and consequently may be expected to give higher decibel figures than would be encountered if high frequency sound waves were utilized For example, Davis et al[16] in 1949 described a perforation of the tympanic membrane after exposure to a 6500 frequency sound at 156-164 dbs for five minutes The low decibel figure attained by these workers may be due to the high frequency of the sound wave (and duration) and lower temperatures (not recorded)

SUMMARY AND CONCLUSIONS

1 The literature concerning tympanic membrane rupture due to air pressure has been reviewed

2 Tympanic membranes of recently deceased human beings have been ruptured by the application of air pressure by way of the external auditory canal, and the myringorupture pressures recorded

3 The tympanic membrane reacts differently to sound pressures from high and low frequency waves, and this study probably more closely resembles results to be found in low frequency sound trauma

4 Some clinical correlations are suggested as related to decibel intensity, air pressure and myringorupture

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LARYNGOLOGIC EXPERIENCE IN BULBAR POLIOMYELITIS [*]

CHARLES P LEBO, M D ,[†]

San Francisco, Calif

> "When you know a thing, to hold that you know it, and when you do not know a thing, to allow that you do not know it this is knowledge" CONFUCIUS, Analects, Book II, Chap XVII

A critical evaluation of the experiences of a consulting laryngologist on the poliomyelitis service of an active, private communicable disease hospital is presented This report may appear to be redundant and ill-timed, since it is written in the wake of a large number of excellent articles on the recognition and management of the respiratory complications of poliomyelitis, published by competent observers, and is offered at a time when the incidence of this dreaded neurotropic virus disease is declining

Why then, does the author have the temerity to undertake the writing of still another paper on this subject? The answer lies in the writer's strong conviction that there remains much to be learned about the prevention, diagnosis, and treatment of the respiratory complications of poliomyelitis At the beginning of his clinical contact with the disease, the essayist prepared himself by means of an extensive review of the pertinent literature and discussion of the subject with physicians qualified by actual clinical experience with poliomyelitis Initially, all phases of the laryngologic management of bulbar poliomyelitis seemed to be very clear to the author, however, as his experience with the disease became greater, he began to perceive that the indications for laryngologic intervention in bulbar poliomyelitis in a disturbingly large number of cases, were not clearly delineated After several

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[†] From the Communicable Diseases Service of Children's Hospital San Francisco Calif and the Division of Otorhinolaryngology Department of Surgery Stanford University School of Medicine

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years of clinical experience with the disease, the author found himself distressed by his progressive inability to give categorical answers to questions posed by members of the house staff, questions which he had previously thought to be easily answerable The writer was thus stimulated to take inventory of his knowledge and ignorance with the aid of a review of the case records of patients in this category admitted to Children's Hospital during the years 1948 through 1956

OBJECTIVES

The objectives of this study are

1 To review the literature concerning the role of the otolaryngologist in the management of bulbar poliomyelitis

2 To study the cases encountered by the author and his colleagues at Children's Hospital and to compare their experiences with those of other groups reporting from similar institutions

3 To describe the *modus operandi* of the poliomyelitis team at Children's Hospital

4 To formulate certain general principles which might serve to guide other otolaryngologists in the therapy of the respiratory complications of bulbar poliomyelitis, and those of other diseases in which analogous problems occur

BACKGROUND

Much has been written during recent years of the respiratory complications of poliomyelitis, and particularly those of the bulbar form of the disease In 1929, Durand[1] published what appears to be the first report concerning the dangers of the hypopharyngeal secretions to the patient with bulbar poliomyelitis He described two cases in which postural drainage appeared to be beneficial Shaw,* in his discussion of this paper, made the following remarks, which may serve well as the theme of this discourse " the tendency of these cases is to progress rapidly to death or to complete recovery " and " successful employment of Dr Durand's method simply removes a great obstacle in the way of complete recovery"

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*Shaw E B Chief of the Communicable Diseases Service Children s Hospital San Francisco Calif

Wilson,[2] in 1931 observed that poliomyelitis may interfere with respiration in three ways *1* directly, by actual paralysis of the intercostals and diaphragm, *2* directly, by involvement of the respiratory centers in the medulla, *3* indirectly, in patients with pharyngeal paralysis, by secretional obstruction with or without associated glottic spasm He stressed the importance of differential diagnosis of the nature of the respiratory difficulty as a basis for rational management He did not mention tracheotomy

In a review article published in 1936 Davison,[3] in reference to the care of patients afflicted with bulbar poliomyelitis, recommended that the foot of the bed be elevated for postural drainage, and that the hypopharyngeal secretions be aspirated frequently Gastric tube feedings, intravenous infusions, and proctoclysis were advocated as methods of choice in providing nourishment for these patients Finally this author stated that in such cases the use of the respirator is contraindicated, but that tracheotomy may be indicated

Wilson,[4] commenting in 1941 upon the use of the respirator emphasized that patients having respiratory difficulty, due to bulbar paralysis, are not helped by this device, but are actually made worse by its use He reaffirmed the importance of careful examination and evaluation of poliomyelitis patients with emphasis upon the differential diagnosis of respiratory difficulty Recommended therapy included postural drainage, aspirations of the pharynx, and even tracheotomy, although no actual experience with the latter procedure is mentioned

The first report of actual tracheotomies in bulbar poliomyelitis (encountered by the essayist in his review of the literature) was that of Galloway,[5] who is 1943 described the use of tracheotomy in two cases, with subsequent recovery in both patients This report also describes a third case in which the patient died during preparation for tracheotomy Two years later, Nelson-Jones and Hunt Williams[6] reported one case of bulbar poliomyelitis, occurring in a British dental officer, with survival after a tracheotomy. In 1947, Hamilton[7] asserted that the indications for tracheotomy are not clear cut, and possibly they may never be.

In their account of 400 cases of bulbar poliomyelitis treated in the Minneapolis epidemic of 1946, Priest, Boies, and Goltz[8] reported 75 tracheotomies. Of the operated patients, 29 recovered. The mortality in the non-tracheotomized group of patients is not included in their report. Galloway and Seifert[9] reported in 1949 concerning 14 patients afflicted with bulbar poliomyelitis, all of whom recovered following tracheotomy. In this classic paper the problem of respiratory complications in poliomyelitis is presented in a concise, yet comprehensive manner. Using drawings of a model, the authors demonstrate the physical basis for the effectiveness of tracheotomy as a by-pass for preventing aspiration of pharyngeal secretions in patients with bulbar paralysis. They stress the need for this tracheotomic by-pass when patients, having pooling of secretions due to pharyngeal paralysis, are placed in respirators. According to these authors, the respirator is not only not contraindicated for patients with bulbar involvement, but that this device is actually helpful to such patients providing they are afforded the protection of tracheotomy. Galloway and Seifert offer the following indications for tracheotomy in bulbar poliomyelitis:

1. Progressive anoxia with secretions in the upper airway.

2. Unconsciousness or pronounced restlessness in a patient who does not respond to other treatment in a few minutes.

3. Pronounced restlessness or stupor in a patient in a respirator, even if the paralysis is apparently of a spinal type.

4. Food accumulation, not otherwise certainly taken care of, in a patient who requires a respirator.

5. Bilateral paralysis or spasm of the vocal cords.

6. Rapidly progressive bulbar symptoms.

7. Grave signs of vasomotor failure.

8. Untrained or inefficient attendants, inadequate equipment, or poor cooperation of the patient, with doubt that the airway will be kept constantly free of secretions

West and Bauer,[11] also reporting in 1949, gave a different set of indications for tracheotomy

1 Definite bulbar signs such as nasal voice, signs of interference with swallowing, and pooling which endangers the airway

2 Bulbar or spinal cases, at first doing well, but later showing gradually increasing anoxia, whether in or out of the respirator

3 Atelectasis

4 Vocal cord paralysis

Lenarsky,[12] reporting in 1950 from the Willard Parker Hospital in New York, questioned the value of tracheotomy in bulbar poliomyelitis, and presented a mortality of 72 7 per cent in tracheotomized cases as opposed to a mortality of 24 4 per cent in non-tracheotomized cases This author advocated that bulbar poliomyelitis patients be treated, not by a single physician, but by a team of specialists, including the internist or pediatrician, the otolaryngologist, the orthopedist, the physiatrist, and the psychiatrist Lenarsky emphasized that the otolaryngologist should not be sought for the tracheotomy alone, but should function as a part of the team in the early treatment of the patient

Stimson,[14] in 1950, presented still another set of indications for tracheotomy These were

1 Bilateral abductor paralysis of the vocal cords This causes a mechanical obstruction which must be by-passed

2 Inability to keep the airway reasonably clear Some clinics with good teamwork can be notably more successful in this than others that are overcrowded or have inadequate or untrained personnel

3 Progressive hypoxia, not otherwise correctible

The same author enumerates the following as disadvantages of tracheotomy

1 The operation is at best an ordeal to the patient, who needs rest and a minimum of handling

2 There are possible complications

3 The mortality following tracheotomy in polio is high

4 The tracheotomy tube narrows the airway and, as a foreign body, it increases endotracheal secretions

5 Tracheotomy makes oxygen administration difficult unless a proper oxygen attachment is available

Since these earlier reports, a multitude of other papers have been published on the subject of tracheotomy in bulbar poliomyelitis Almost without exception, these accounts have echoed the reasoning of Galloway, and have confirmed his results

REPORT OF CASES

During the years 1948 to 1956 inclusive, the total number of poliomyelitis cases admitted to Children's Hospital was 2,158 Of these cases, 345 were of the bulbar and bulbospinal types, the overall mortality in this group was 19 4 per cent, or 67 deaths Tracheotomies were performed in 40 cases having bulbar involvement There were 15 deaths (37 5 per cent) in the tracheotomized group Endotracheal intubation, planned as a temporary measure, was performed in six moribund, comatose, respirator cases, all of which expired

Fig 1 shows, year by year, the total number of patients with bulbar involvement, their mortality, and the number of tracheotomies performed This table demonstrates graphically that, in our series of cases, no apparent relationship exists between the total number of cases, the number of tracheotomies performed, and the mortality statistics As an example of this lack of correlation, let us compare the years 1951 and 1952 In the year 1951, 67 cases of bulbar and bulbospinal poliomyelitis were admitted to Children's Hospital, in this series of cases two tracheotomies were performed and the overall mortality was 12 cases or 17 8 per cent In the year 1952, of a total of 59 cases with bulbar involvement, there were ten tracheotomies, nine deaths, and an overall mortality of 15 2 per cent Certainly the case data from 1951 and 1952, as well as those of the other years included in this study, do not enable one to conclude that the mortality experience in bulbar and bulbospinal poliomyelitis cases at Children's Hospital was significantly influenced by the number of treacheotomies performed

Fig 2 indicates that in our series of patients, the mortality in the bulbar cases was approximately twice that occurring in the bulbospinal cases Shaw[10] explains this finding on the basis that patients with bulbospinal poliomyelitis tend to have mild, widely-disseminated central nervous system involvement, while patients with pure bulbar poliomyelitis are more likely to have more severe local involvement occurring in vital centers

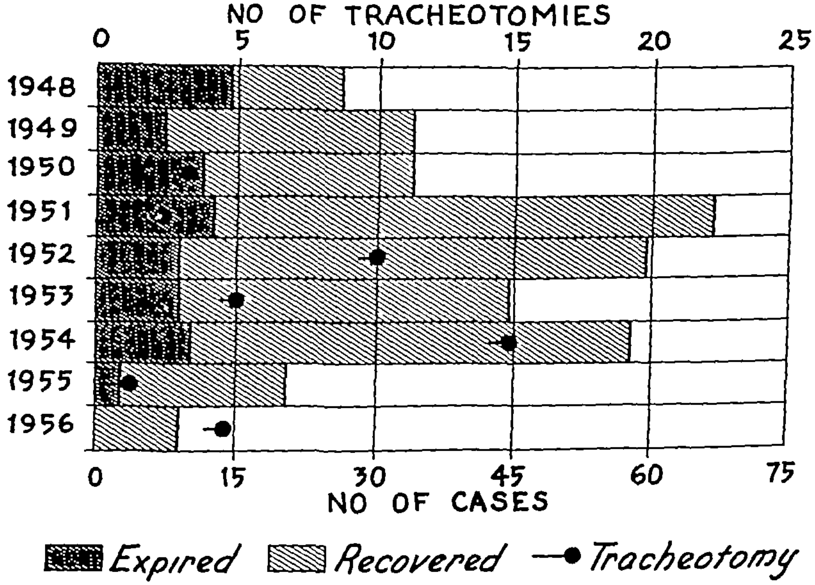

Fig 1 A graph showing the total number of bulbar and bulbospinal poliomyelitis cases year by year together with data concerning the mortality experience and the number of tracheotomies performed

A comparison of our experience with that of four other groups is illustrated in Fig 3 In the percentage of bulbar

Type	Total Cases	Mortality
Bulbar	115	33 or 28 7%
Bulbospinal	230	34 or 14 8%

Fig 2 The comparative mortality experience at Children s Hospital in bulbar polio myelitis and in bulbospinal poliomyelitis during the years 1948 to 1956 inclusive

Reporting Group or Institution	Total No Bulbar Cases	Tracheotomy Cases	Deaths in Tracheotomy Cases	Deaths in Non-Tracheotomy Cases
Minneapolis Gr , 1946	400	75 (18 7%)	46 (61 3%)	not specified
Evanston Hospital, 1947 50	63	25 (39 6%)	—— 10 ——	
Los Angeles County Hospital				
a 1946	129	14 (10 8%)	7 (50%)	31 (26 9%)
b 1948	600	230 (38 3%)	—— 123 ——	
Willard Parker Hospital N Y 1948 1949	171	11 (6 4%)	8 (72 7%)	39 (24 4%)
Children s Hospital San Francisco 1948 1957	345	40 (11 6%)	15 (37 5%)	52 (17 0%)
Combined Experience (based upon specified data in each category)	1708	395 (23 1%)	76 (54 3%)	122 (18 9%)

Fig 3 This chart is a comparative compilation of the experience of the designated groups or institutions with tracheotomy in bulbar poliomyelitis. The percentages expressed are based only on those reports which included a complete breakdown of data within the terms of reference of this chart.

cases tracheotomized, Children's Hospital occupies a median position Our *death rate in both the tracheotomized patients* and in the non-tracheotomized patients is the lowest of all groups in whose reports these statistics are specified Like the investigators at Los Angeles County Hospital and at Willard Parker Hospital, we found the mortality to be higher in the tracheotomized bulbar cases than in the non-tracheotomized bulbar cases

LARYNGOLOGIC MANAGEMENT OF POLIOMYELITIS CASES AT CHILDREN'S HOSPITAL

The facilities at this institution are particularly favorable for the care of poliomyelitis patients The communicable disease building is well equipped, and is generously staffed with resident physicians, interns and experienced nursing personnel During the period covered by this report a group of consulting laryngologists participated on a "poliomyelitis team" which, in addition to the attending physicians and the house staff, included anesthesiologists The laryngologists were consulted as early as possible, thereby giving them the opportunity of following each case with manifest or developing bulbar involvement, and thus enabling them to gain a dynamic perspective of each individual problem Because of the care it was possible to render under these circumstances, the indications for tracheotomy at Children's Hospital differed from those reported by physicians working in similar institutions

TRACHEOTOMY

The indications for tracheotomy at Children's Hospital are best presented in reference to those of Galloway, which are widely accepted as the standard indications for this surgical procedure in poliomyelitis Galloway's first indication (progressive anoxia with secretions in the upper airway), his fifth indication (bilateral paralysis or spasm of the vocal cords), and his sixth indication (rapidly progressive bulbar symptoms) are considered to be quite important by the author and his colleagues

We differ from Dr Galloway in reference to his second (unconsciousness or pronounced restlessness in a patient who does not respond to other treatment in a few minutes), and third (pronounced restlessness or stupor in a patient in a respirator, even if the paralysis is apparently of a spinal type) indications It is our opinion that it is imperative in such situations to determine the etiology of the restlessness or of the comatose state before instituting therapeutic measures, tracheotomy, under the conditions specified in these two indications, may often be inappropriate therapy

Indication four (food accumulation not otherwise certainly taken care of in the patient who requires a respirator) is not generally applied, since the use of intravenous and tube feedings eliminates this problem, however, such patients require extremely close observation and may have need for tracheotomy for other reasons.

While indication seven (grave signs of vasomotor failure) may be the result of prolonged hypoxia, such findings may also be due to medullary involvement by the disease process *per se*, hence we do not, as a rule, perform tracheotomies merely on the basis of vasomotor failure.

As some of the foregoing remarks have implied, indication eight, which concerns problems relative to personnel and equipment, is one that we have not had to apply at Children's Hospital. On the contrary, it is believed that many of the bulbar poliomyelitis cases which were treated successfully at this institution without tracheotomy would have been tracheotomized at most other hospitals.

In reference to the indication concerning bilateral vocal cord paralysis, the poliomyelitis team at Children's Hospital considers the presence of unilateral vocal cord paralysis, or paresis, to be a valid indication for tracheotomy, all other factors being considered. Another indication referred to by Galloway, but not included in his list, concerns the patient with mild bulbar involvement, in whom progressive respiratory paralysis necessitates his transfer to a respirator. It has been our policy to protect such patients with preliminary tracheotomies.

Although the indications of Galloway, with the aforementioned modifications, are generally employed at Children's Hospital, the author and his colleagues prefer not to adhere to any specific set of indications. In all patients, the indications for tracheotomy are considered in the light of many important factors, such as the general condition of the patient, the stage and severity of the disease, the presence of pulmonary complications, and the level of consciousness. We consider the situation to be far too complicated to permit the use of any categorical list of indications; nonetheless, we recognize the value of such a list of indications in hospitals in which bulbar poliomyelitis is not frequently encountered.

The main considerations in regard to the indications for tracheotomy in this disease revolve around a careful initial examination of the patient, which must include either indirect or direct laryngoscopy When the findings of the initial examination do not indicate tracheotomy, the laryngologist is then obligated to follow the patient with as many subsequent examinations as may be needed for careful evaluation of the patient's progress We have employed the policy of utilizing postural drainage, pharyngeal aspiration, and other conservative measures in order to evaluate and manage all bulbar patients who were not obvious candidates for immediate tracheotomy

The following case reports are presented as illustrations of typical situations in which we have not performed this surgical procedure

Case 1 H N, a 37 year old male physician, was admitted on Sept 17, 1952, with a history of sore throat and fever for five days, gagging and vomiting for two days, and inability to swallow for six hours Initial examination disclosed a well developed and nourished, apprehensive person with rhinolalia, hoarseness and gurgling speech The patient was neither able to cough nor to swallow his secretion The positive physical findings included marked weakness of the soft palate with deviation of the uvula to the left, pronounced weakness of the pharyngeal constrictors, greater on the right, and a mild but definite adductor paresis of the right vocal cord The intercostal muscles and the diaphragm were judged to function normally No weakness nor spasm was demonstrable in the extremities The lungs were clear

The patient was given a diagnosis of acute bulbar poliomyelitis and was treated by means of postural drainage, intermittent suctioning of the pharyngeal secretions, and feeding via nasal tube It was the decision of the staff that this patient, having weathered the storm, would probably continue to improve under conservative management Tracheotomy was deferred

The fever, which was 39° C rectally on admission, lysed rapidly The patient was afebrile by Sept 19, 1952 On Oct 8, 1952, the feeding tube was removed and the patient was discharged four days later

COMMENT

This case report has been included in order to illustrate a statement made earlier in this paper to the effect that the indications for tracheotomy in bulbar poliomyelitis should be tempered with consideration of the stage of the disease process Certainly this patient would have done very well with a tracheotomy, yet the staff reasoned that since H N appeared to be near the end of the acute phase of his disease and had reached this point without the development of pulmonary complications, tracheotomy might be avoided so long as the clinical picture continued to improve

Case 2 V M a five-year-old boy, was admitted on Aug 29 1954 with a history of vomiting and fever of two days' duration and of headache and backache for one day prior to admission The initial physical examination revealed slight neck stiffness partial left sided facial paralysis weakness of the pharyngeal constrictors associated with a moderate degree of pooling and a rectal temperature of 40° C The sensorium was clear No cyanosis was observed The function of the respiratory muscles was unimpaired

At a conference held on the date of admission it was predicted that since this child was in an early phase of his disease progression was likely to occur Accordingly the boy was given postural drainage intermittent pharyngeal aspirations tube feeding, and close observation On Aug 30 1954 progression was evidenced by beginning intercostal paralysis increased rightsided facial weakness and slight lethargy without cyanosis It was then decided that immediate tracheotomy should be performed

The operation was completed without incident under general anesthesia a No 2 snorkel tracheotomy tube being inserted[21] Postoperatively the child was placed in an open topped tent which was ventilated with oxygen containing a nebulized detergent.* Forty-eight hours post operatively because of increasing respiratory paralysis with attendant diminution of his tidal volume the patient was placed in a tank type respirator His initial adjustment to the machine was good, and progressive improvement began The patient was removed from the respirator after five days and was extubated two days later He was discharged from Children s Hospital on Sept 20, 1954

COMMENT

The case of V M is presented for contrast with Case No 1 The boy was very ill, and still in an early stage of his disease, when admitted It was anticipated that progression would occur, and unfortunately this prognosis was valid It became necessary to perform a tracheotomy and eventually, to place the child in a respirator In retrospect, it would not have been improper to perform the tracheotomy on the day of admission This case serves to reinforce the thesis that the indications for tracheotomy in bulbar poliomyelitis should be tempered by the chronology of the disease process

Case 3 Mrs S M a 41year-old housewife was admitted to Children s Hospital on Aug 4 1951 twenty four hours after the sudden onset of headache fever and inability to swallow On admission, the patient was quite restless and presented a complete paralysis of the left facial nerve deviation of the tongue to the right, pooling of secretions in the hypopharynx fixation of both vocal cords in abduction and the characteristic signs of meningeal irritation Although she was dusky in color initially her color improved promptly with elevation of the foot of her bed, nasal oxygen and intermittent pharyngeal suctioning

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*Alevaire Winthrop Laboratories New York

One hour after admission the patient suddenly became cyanotic and appeared to have no respiratory exchange She was immediately placed in a tank respirator and was provided with an endotracheal airway Again her color improved, particularly after aspiration of the contents of the tracheobronchial tree through the endotracheal tube The patient maintained this improvement for 90 minutes, and then expired

COMMENT

This woman suffered an overwhelming invasion of her central nervous system by the poliomyelitis virus In her management, the insertion of an endotracheal tube offered all that might be expected from a tracheotomy, but did not expose her to a surgical procedure at a time when her life was in jeopardy Had she responded to therapy, a tracheotomy would have been performed before removal of the endotracheal tube

Endotracheal intubation has a very definite place in the management of bulbar poliomyelitis Certainly, it is a desirable substitute for an emergency tracheotomy Another advantage of the procedure is that it may be done at any hospital by the anesthesiologist on duty, should the arrival of the otolaryngologist be delayed

TECHNICAL CONSIDERATIONS

It so happened that local and general anesthesia were used with equal frequency in the entire series of cases Local anesthesia predominated in the earlier years, while general anesthesia predominated in the more recent years Both types of anesthesia were found to be satisfactory and well tolerated, even in very sick patients[31] General anesthesia was initially employed to facilitate the care of respirator patients, but as our experience with this technique grew, we elected to use it also in patients whose disease did not necessitate the use of the respirator Currently at Children's Hospital, general anesthesia is considered the method of choice for respirator cases and is utilized interchangeably with local anesthesia in non-respirator cases

Whenever possible, patients requiring tracheotomy were removed to the operating room of the communicable disease building Respirator patients were usually transferred to an operating table as a preliminary to tracheotomy Removal of the patients from the respirators was accomplished after induction of general anesthesia, with endotracheal intubation enabling the anesthesiologists to render artificial respiration throughout the procedures It was thus possible to avoid the pitfalls of performing this operation in the respirator Artificial respiration after insertion of the tracheotomy tube, and before replacement of the patient in the respirator, was simplified with the use of the snorkel tracheotomy tube[21] It is pointed out that this special tracheotomy tube has also been helpful in facilitating the respirator care of tracheotomized patients (The snorkel tracheotomy tube is illustrated in Figs 4, 5)

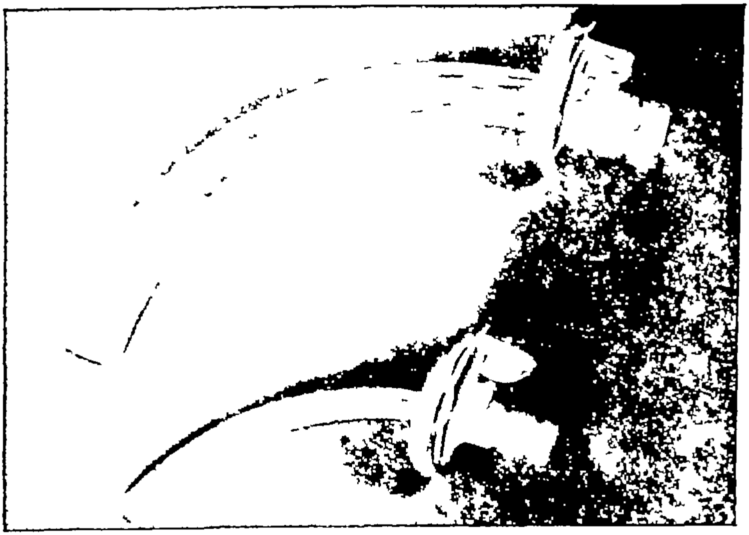

Fig 4-A. Lateral view of snorkel tracheotomy tubes in sizes No 5 and No 0

BRONCHOSCOPY

While bronchoscopy as a single or repetitive procedure is

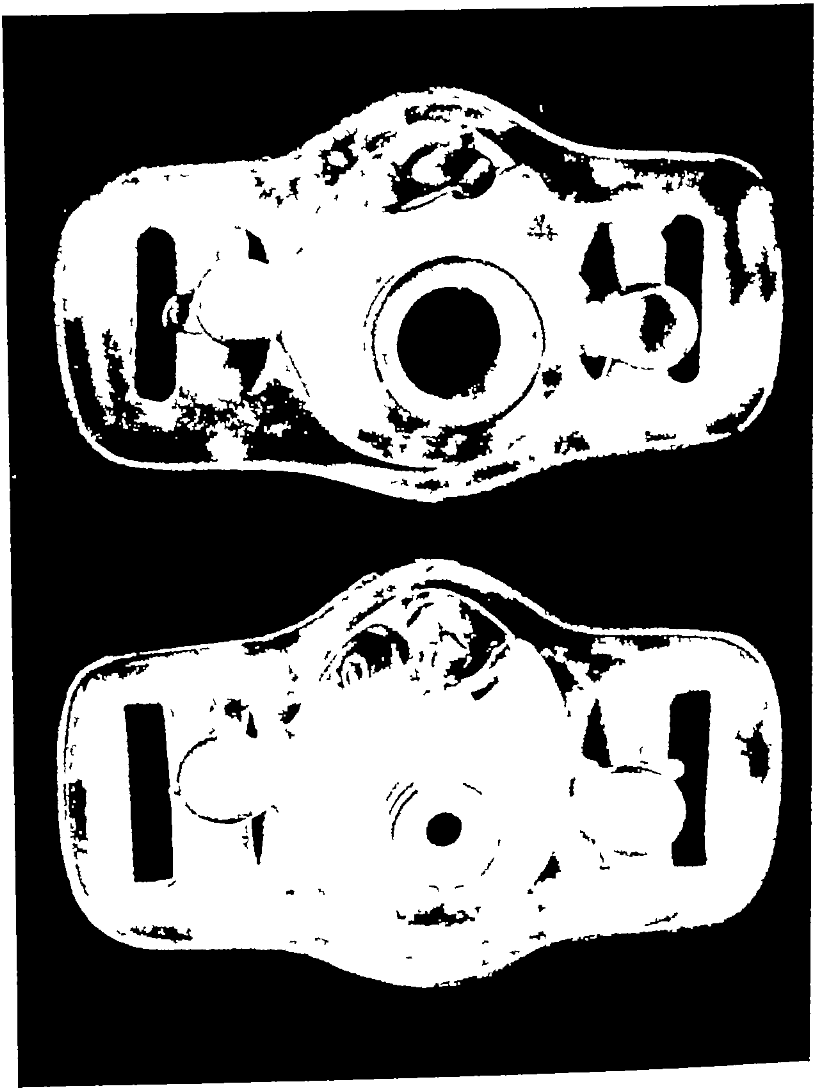

Fig 4-B Anterior view of snorkel tracheotomy tubes in sizes No 5 and No 0

often performed independently of tracheotomy in bulbar poliomyelitis, it was frequently undertaken as a preliminary to this surgical procedure When a bronchoscopy preceded a tracheotomy, the bronchoscope was usually left in the trachea during the surgery By means of a heavy flow of the anesthetic mixture, artificial respiration was administered very satisfactorily through bronchoscopes of the type which is fitted with an oxygen adapter near the proximal end[32]

We have favored general anesthesia for peroral bronchoscopy in nontracheotomized respirator patients because we have seldom obtained satisfactory topical anesthesia in this group of patients The difficulty in inducing adequate topical anesthesia in this group is attributed to both the pooled secretions in the pharynx and to the recumbent position Under these circumstances thiopental sodium and a curarizing agent are administered intravenously The respirator provides artificial respiration during anesthesia as well as in the preanesthetic and postanesthetic periods General anesthesia is not required in bronchoscopic procedures performed through tracheotomies In this instance topical anesthesia is employed, except for comatose patients in whom no anesthesia is required A major advantage of tracheotomy is that it facilitates bedside bronchoscopy

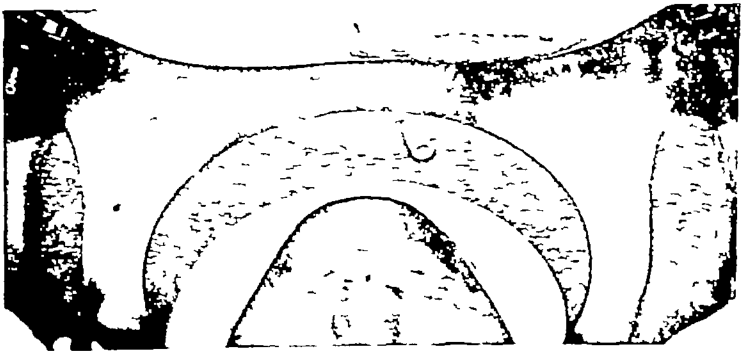

Fig 5 Illustration of snorkel tracheotomy tube in use as viewed from outside of respirator Note the end of the tube emerging from the sponge rubber collar of the respirator this is an endotracheal tube the opposite end of which is attached to a snorkel tracheotomy tube inside the respirator

POST-TRACHEOTOMY CARE

As pointed out by Negus,[33] the previously anoxic patient may be in danger after a successful tracheotomy because of apnea induced by a rapid loss of excess carbon dioxide resulting from restoration of an adequate airway at a time when the chemoreceptors are no longer responsive to the normal range of plasma carbon dioxide concentrations Although no complications of this sort were encountered in our series of cases, we have been aware of this possible danger and have taken the recommended precautions against it

It is considered advisable to change tracheotomy tubes every 48 hours for the first seven to ten days, and twice weekly thereafter Although extra large tracheotomy tubes have been advocated by other workers,[34] we have not encountered a need for their use

The procedure of aspiration of the tracheobronchial tree through the tracheotomy tube is to be undertaken with caution, since pulmonary complications may follow traumatic suctioning Plumb and Dunning,[35] and Conley,[36] have emphasized these dangers, and both have suggested methods of avoiding such trauma

EXTUBATION

It is believed that allowing the tracheotomy tube to remain in place should be considered to be just as active a process as electing to perform the tracheotomy The tracheotomy tube, which is no longer needed, is both a physical and psychological detriment to the welfare of the patient who wears it The duties of the laryngologist do not end with the termination of the acute phase of the tracheotomized poliomyelitis patient's illness, he is obligated to follow the progress of the patient and to extubate at the proper time Successful extubation demands the judicious use of the art of medicine and requires a positive, confident attitude on the part of the laryngologist

The tracheotomy tube constitutes a foreign body, and as such evokes the formation of excessive secretions The presence of such secretions does not necessarily indicate that the tube is still needed

DISCUSSION

Many reports of tracheotomy in bulbar poliomyelitis list groups of cases in which tracheotomy is regarded as a life-saving procedure This author is unable to conclude that tracheotomy was life-saving nor that this procedure was not life-saving in any of the surviving cases included in this report The clinical picture is far too complicated Many of our patients exhibited dramatic initial improvement after tracheotomy, but subsequently died, some patients showed no change after tracheotomy, but recovered, other patients maintained whatever improvement followed tracheotomy

Most authors stress the importance of clinical hypoxia in their lists of tracheotomy indications and include restlessness, anxiety, hyperpnea, flushed fascies, tachycardia, lethargy, coma, and cyanosis as manifestations of hypoxia In this they are indeed correct, however, most of the features of this clinical picture also occur in viral invasion of the higher centers, in hypokaliemia, and in disturbed acid-base balance, hence the presence of the aforementioned symptoms and physical findings is not specific Even when hypoxia is demonstrated by oximetry, these other conditions may also be present It may, therefore, be concluded that tracheotomy is most useful in those cases in which these "hypoxic symptoms" are due primarily to hypoxia resulting from respiratory obstruction in the hypopharynx and in the cephalic portions of the tracheobronchial tree Tracheotomy may be futile when these "hypoxic symptoms" are principally the result of conditions other than hypoxia

The differential diagnosis of the etiology of "hypoxic symptoms" is most difficult, even with the assistance of laboratory tests, which time may not always permit This differential diagnostic problem, however, should not deter one from performing a tracheotomy if the procedure appears to be indicated The coexistence of extensive spread of the virus in the medulla, altered electrolyte metabolism, and impaired acid-base equilibrium with primary and secondary hypoxia accounts for a large proportion of the deaths occurring in tracheotomized (as well as non-tracheotomized) bulbar and bulbospinal poliomyelitis patients

It is considered significant that no complications attributable to tracheotomy were encountered in any of the patients in this series; furthermore, evaluation of the records (including autopsy reports) of patients expiring after tracheotomy in no case indicated that tracheotomy was a factor contributing to the patient's demise Stimson[14] states that the mortality following tracheotomy in poliomyelitis is high; it is conceded that Stimson is correct in this contention *The reason for the high death rate in tracheotomized poliomyelitis patients is that this operation is usually performed on patients afflicted with the severest forms of this disease, and in whom the anticipated mortality is very high* It is believed that the mortality scores for tracheotomized poliomyelitis patients would, in all series, be significantly higher if these patients had not been afforded the benefits of tracheotomy

The task of evaluating therapeutic procedures in poliomyelitis is most difficult Since this disease exhibits marked annual and geographic variations in incidence and severity, controlled studies are not feasible As is illustrated in Fig 1, there is no constant relationship in our series of cases between the incidence of bulbar poliomyelitis cases, their mortality, and the number of tracheotomies performed This observation serves to point out the fallacy of attaching too much significance to reports of the results of tracheotomy in poliomyelitis which include but one year, or even a few years, of experience

SUMMARY

A comparison of nine years of experience at Children's Hospital with 345 cases of bulbar poliomyelitis, with similar experience reported by four other groups demonstrated that

1 Children's Hospital occupied a median position in regard to the percentage of such cases in which tracheotomy was performed

2 The mortality experience at Children's Hospital in both tracheotomized and in non-tracheotomized bulbar poliomyelitis cases is the lowest of that of all groups specifying these statistics

No definite conclusions are drawn from the case data included in this report All that may be said is that the experience of the staff of Children's Hospital did not differ significantly from the experience reported by others working with this disease

CONCLUSIONS

1 The indications for tracheotomy in bulbar and in bulbospinal poliomyelitis are ill-defined Therapy based upon the standard indications may often be inappropriate Each case must receive consideration as an individual problem

2 Tracheotomy is most beneficial when done early, *i e* before the occurrence of pulmonary complications and hypoxic central nervous system damage, both of which the operation is intended to prevent

3 General anesthesia, in our experience, is a safe and satisfactory technique for use in bulbar poliomyelitis It permits removal of the respirator patient from the respirator, and thus avoids surgical complications due to inadequate exposure

4 Bronchoscopy is a valuable adjunct in the management of bulbar and bulbospinal poliomyelitis, and may be employed for the prevention as well as the treatment of, pulmonary complications

5 The necessity for meticulous evaluation of the bulbar poliomyelitis patient by the team of consultants, both initially, and at each stage of the disease, cannot be overemphasized

6 The use of endotracheal intubation, both in lieu of emergency tracheotomy and as a means of providing a temporary airway for very ill patients, is recommended

7 Whenever in the management of bulbar poliomyelitis patients the need for tracheotomy cannot be ruled out, the operation should be performed

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ments have given support to the hypothesis that elevated temperatures and humidities, and contamination with gram-negative bacilli, play an important role in production of some diseases of the external auditory canal. Much has been written regarding the role of infection in the pathogenesis of diseases of the external ear, and recently this subject was thoroughly reviewed.[1]

During the Second World War numerous cases of external otitis occurred among troops stationed in tropical and subtropical latitudes, and it was thought that elevated temperatures and humidities were factors in the development of the dermatoses.[2-8]

Horne[9,10] showed a relationship between the incidence of such diseases as miliaria and the minimum dry bulb temperature and humidity in India. Senturia[11] and Bianca[12] correlated high temperatures and humidities with the incidence of external otitis in certain regions of the United States. On the basis of clinical laboratory observations, the former postulated that prolonged exposure to these environments permitted the absorption of moisture by the stratum corneum, interruption of normal keratinization, plugging of the apopilosebaceous units and, therefore, interference with the delivery of the antimicrobial substances to the surface of the skin of the ear canal.[13]

There are also other indications that the absorption of moisture by the stratum corneum in a hot, humid environment may be related in some manner to the high incidence of external otitis. Mali[14] noted that the permeability of the skin rose with an elevation of environmental relative humidity. Buettner[15] was of the opinion that water and water vapor pass into nonsweating skin in proportion to the surrounding air vapor pressure. Mole[16] and Blank[17,18] demonstrated that the stratum corneum will take up moisture from a high humidity environment. Blank[17] clearly showed that cornified epithelium absorbs increasing amounts of moisture as the relative humidity rises.

Gaul and Underwood[19] suggested that a reduced amount of moisture in the air will influence the pliability, softness and

STUDIES OF FACTORS CONSIDERED RESPONSIBLE FOR DISEASES OF THE EXTERNAL EAR [*][†]

I Survival of Exogenous Bacteria in the External Auditory Canal Under Varied Conditions

BEN H SENTURIA, M D ,
and
CHARLES D CARR, M T ,
St Louis, Mo

INTRODUCTION

The factors suspected of contributing to diseases of the external auditory canal are numerous Some investigators believe that prolonged exposure to high temperatures and high relative humidities is of prime importance in the production of external otitis On the other hand, it has been proposed that low relative humidities and low temperatures, leading to desiccation of the skin, constitute a means by which the natural defense mechanism of the skin is overcome Others are of the opinion that removal of surface lipids and/or trauma break the natural barrier against infection and may, at the same time, provide the means by which exogenous microorganisms are implanted on the surface of the skin

In this study, attention has been directed towards some of these factors, *viz* , temperature, humidity, trauma and the removal of the surface lipids, as they influence the survival of exogenous organisms in the external auditory canal of the cat

LITERATURE REVIEW

Reports of external otitis occurring in hot, humid environ-

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[*] From the Washington University School of Medicine Department of Otolaryngology St Louis Mo

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organisms or fungi onto the untraumatized skin but demonstrated extensive morphologic changes following contamination and the application of various irritating acids. Salvin[30] introduced a suspension of *Pseudomonas aeruginosa* after excoriating the ears of rabbits, and produced vesicles and papules. Fluid from the vesicles was removed, and "in all cases, pure cultures of the isolate originally inoculated into the ears were obtained." Haley[31] showed that trauma to the skin of the ear canal was a necessary factor in the experimental production of mycotic infections in the rabbit. More recently, Senturia and Liebmann,[32] using cats, demonstrated that contamination or trauma alone did not produce external otitis, but after trauma and contamination with pseudomonas organisms, morphologic and pathologic changes were consistently produced.

Perry and Nichols[33] "liberally seeded" *Pseudomonas aeruginosa* into the untraumatized external auditory canals of human volunteers. One week later the organism could not be recovered, and no clinical evidence of external otitis could be found. Senturia[1] described eight healthy ears with normal bacterial flora in which acute diffuse external otitis developed seven to 17 days after irrigation for removal of ear wax. Positive cultures for *Pseudomonas aeruginosa* were obtained in all cases.

The absence of lipids on the surface of the skin is believed to be a factor in the occurrence of diseases of the external ear.[1] The bactericidal and fungistatic action of the skin lipids may be an important factor in the inhibition of microbic growth as suggested by Ricketts et al,[34] Burtenshaw[35] and Peck et al.[36]

It has been postulated that high environmental temperature and relative humidity decrease the viscosity of the sebum layer, causing the lipids to spread thinly over a much greater surface area and preventing the formation of an adequate protective coating.[37-39] Gessert et al[40] were unable to demonstrate any decrease in the lipid covering of the cat and rabbit ear canals after the animals had been exposed to high temperatures and humidities (see Part II).

smoothness of the skin Blank[20] proposed that a loss in the flexibility and fissuring of the stratum corneum occur when there is a reduction in the moisture content of the skin under conditions of low relative humidity

Swimming under water and diving can bring about the production of skin maceration and secondary infection of the external ear canal Failure to remove all the water present in the meatus after swimming was considered the cause of external otitis by Gordon[21] Punt[22] noted that most of the cases of ear diseases occurred not only during hot, humid weather but also after patients had been swimming

On the other hand, numerous patients deny any history of swimming prior to symptoms of external ear inflammations[1] In a series of experiments, Collins[23] produced maceration and desquamation but no secondary infection after filling the osseous portion of the ear canal with chlorinated swimming pool water or sea water Collins concluded that this factor alone was not enough to cause external otitis Senturia, however, reported the development of acute external otitis following irrigation of the ear canal with hypertonic saline for the routine removal of ear wax in 13 normal ears[1]

A factor often implicated in the production of external otitis is trauma produced by the insertion of foreign objects into the ear canal[4,24,25] In a study by Syverton et al,[26] it was recorded that 50 per cent of the patients habitually picked at the ear canal Infection associated with the traumatic removal of foreign objects from the meatus has been described frequently[1,27]

In observing the effects of trauma and increased humidity on the skin of the meatus, Shelley and Perry[28] obstructed the external ears of adult males by inserting ear plugs and/or applying small strips of adhesive tape to the canal wall One-half of the subjects showed no changes, while the other half showed a "soggy maceration" of the skin of the canal, which the investigators believed resembled "hot weather ear"

Senturia, experimenting with mice and rabbits at the School of Aviation Medicine,[29] was unable to produce gross lesions of the ear canal by the introduction of pseudomonas genous and exogenous skin bacteria, Pillsbury and Rebell[49] found that various bacteria applied to normal and pathologic skin were markedly decreased after desiccation Cornbleet and Montgomery,[50] using *Staphylococcus aureus* on various parts of the body, found that moist areas were poor in self-sterilization, and that this power was restored when the skin area was exposed to the air and allowed to dry

Colebrook[51] showed that approximately 29 per cent of *hemolytic Streptococci* placed on the skin remained viable for one hour and 4 per cent for two hours after drying *E coli*, Proteus and Klebsiella appeared to be sensitive to skin-sterilization Burtenshaw[52] performed similar observations to Colebrook's[51] using streptococci on various skin areas, and suggested that slow self-disinfection occurred after the desiccation phenomenon was over Colebrook and Maxted[53] pointed out that *Streptococcus pyogenes*, not normally present on the skin of the hands, would spontaneously disappear when artificially implanted on it They stated that the Coli, Proteus and Friedlander bacilli would also disappear in the same manner

Price[54] noted that implanted *B subtilis* could not be found on the hands and arms after three hours, while exogenous staphylococcus, *B coli* and *Pseudomonas aeruginosa* persisted on the hands for many weeks despite scrubbing and application of germicides He was of the opinion that certain exogenous microorganisms seemed to be able to adapt to the new environment Prolonged exposure of the skin to these contaminants could result in their becoming endogenous organisms, and once this transition had occurred the skin could not easily be disinfected

Rebell et al[55] reported a series of experiments in which *E coli* staphylococcus and streptococcus (Group G) were the test organisms in determining the self-sterilizing ability of the skin Staphylococci were found to be more resistant to autogenous sterilization than *E coli* When the skin lipids were removed prior to contamination, it was noted that there was a marked decrease in the ability of the skin to sterilize itself It was further shown that in test subjects exposed to high temperatures and humidities for a period of eight hours after inoculation of the skin with *E coli* the contaminant was

It is generally accepted that contamination with Gram-negative bacilli plays an important role in the production of diseases of the external ear Schiemann and Landau[41] showed that a bacterial suspension, especially Gram-negative bacilli, placed on the normal skin of the hand were rapidly destroyed, and they believed that this destruction was due to some mechanical or chemical action Arnold et al [42] stated that *E coli* and *S typhosa* would remain viable on dirty or fatty skin for short periods Singer and Arnold[43] showed that the skin, after being washed with soap and warm water, was able to destroy from 90 to 95 per cent of the *B prodigiosus*,* *B pyocyaneus*, *S typhosus*, *S paratyphi*, *S enteritidis*, *E coli*, *S aureus* and *S albus* within 10 minutes after being applied to the skin When these same microorganisms were applied to dirty or fatty skin they disappeared more slowly

Montgomery[44] studied the destruction of *B prodigiosus* on fingers which were submerged in various dilutions of bacteria and air-dried for 15 minutes It was noted that the higher the dilution, the greater the percentage of bacteria destroyed In the undiluted suspension only 25 per cent of the bacteria were destroyed, while 90 per cent were eliminated in the 1 200 dilution In similar experiments performed by Karns and Arnold,[45] using a 1 50 saline dilution of *B prodigiosus*, 91 per cent of the bacteria were found to be killed in 60 minutes These authors believe that despite considerable variations in results, the skin showed a 100 per cent disinfecting power for these bacteria

Norton and Novy[46] and Bryan and Mallmann[47] disagreed with the findings of Arnold and his associates,[41] and attributed the reduction of bacterial counts to desiccation rather than any specific antibacterial action Arnold and Bart[48] presented data to show that there was no decrease in the rate of disappearance of organisms kept on moist skin, and no increased sterilizing ability of the skin after scrubbing with soap and water and cleansing with alcohol and ether They reiterated their belief that factors other than desiccation played an important role in the disappearance of the organisms

In a study of the factors influencing the growth of endobacteria *Pseudomonas aeruginosa,* hemolytic *Micrococcus aureus* and *Beta-type Streptococcus*

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*Serratia marcesens

Biochemical reactions for conclusive identification of the Gram-negative bacilli were performed according to the procedures suggested by Edwards and Ewing[56] Coagulase and mannite fermentation tests were made on all strains of micrococci used as contaminants Only those micrococci which gave a strongly positive reaction with these tests were utilized

In those experiments in which dilutions were prepared, the organism was grown in broth, then serial dilutions were made to the required suspensions After incubations for one hour at 37° C, 0 5 ml of broth suspension was instilled into the ear canals A light cotton packing was inserted into the orifice of the canal to prevent periauricular contamination Plate counts, performed simultaneously on the diluted suspensions, gave an indication of the number of organisms present *

Removal of the surface lipid film from the skin of the cartilaginous ear canal was accomplished by using two ether-saturated cotton swabs Trauma was produced by gently stroking the skin of the ear canal with a ringed metal ear curette until erythema developed Trauma sufficient to cause bleeding was avoided

Morphological changes in the skin lining the external ear canals consisted of various degrees of erythema (R), exudate (X), crusting (C), edema (E) and dryness (D) The degree of change was noted as from 4-plus (indicating severe involvement) to plus-minus when only slight changes were found

When anesthesia was considered desirable, pentobarbitol sodium (approx 12 mg per pound of body weight) was injected intrathoracically in cats The majority of animals were completely recovered within four to five hours

The temperature in the hot room was controlled automatically† and the humidity sustained within the planned range

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*10^{6} = 1040 colonies ml
10 = 388 colonies/ml

†Two Chromolon electric heaters thermostatically controlled by Mercold Switch

recovered from a majority of subjects one to two weeks later These observations concurred with an earlier experiment of this same study, in which it was demonstrated that *E coli,* and staphylococcus, kept moist by spraying, showed a prolongation in survival time In a later report, Pillsbury and Rebell[49] found *A aerogenes, Ps aeruginosa, Pr vulgaris,* and *E coli* to be somewhat more resistant to fatty acids of sebum than *M epidermidis, albus, candidus, flavus* and coagulase-positive micrococci The *Corynebacteria (xerose* and *tenuis)* were also slightly sensitive to some fatty acids

METHODS AND TECHNIQUES

The skin lining the external auditory canal of the cat has been shown to have skin appendages similar to those of the human (*viz ,* apocrine and sebaceous glands) and, therefore, this animal was chosen for use in this study Only animals which had been through a quarantine period and showed no signs of either systemic or local disease were selected The animals were housed in separate cages and fed a balanced diet

Cultures for bacteria and fungi of the external auditory canal were routinely taken on all animals before and after procedures were performed The swabs were inoculated onto MacConkey, Sabouraud's and blood agar plates * In the later series of experiments, swabs of the external ear canals were placed immediately into Tryptose broth, incubated for one hour at 37° C , and then 0 1 ml of the broth was inoculated to solid culture media The material was spread over the surface, with an "L" shaped wire needle in order to obtain isolated colony growth The number of bacterial colonies was recorded as follows 0 = #, 1-25 = ±, 26-50 = +, 51-75 = 2+, 76-100 = 3+, >100 = 4+

The microorganisms used to contaminate the external auditory canals of the experimental animals were obtained from patients suffering from acute diffuse external otitis, chronic otitis media or mastoiditis These included the following in very small numbers The Pseudomonas group was not found in the normal human or cat meatus

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*Citrated whole human blood and defibrinated rabbit blood were used in the preparation of blood agar plates

Experiment B

This experiment was designed to determine the effect of high temperatures and high relative humidities on the bacterial flora and morphology of the skin of the normal external auditory canal of the cat

Two groups of cats were selected one group of eight cats (16 ears) were placed for a period of four days in a room in which the average temperature was 86° F and the average relative humidity 95 per cent Another group, consisting of 20 animals (28 ears)* were exposed to the approximate temperatures and humidities of the first group for a period ranging from four to 17 days

TABLE II —EXPERIMENT B

Effect of High Temperatures and Humidities upon the Bacterial Flora and Morphology of the Cat External Auditory Canal

Av T * = 86° F Av R H † = 95%

No of Cats	No of Ears	Period of Observation	Bacterial Flora	Morphology
8	16	4 Days	Unchanged	Unchanged‡
20	28	4 17 Days	Unchanged	Unchanged

*T = Temperature
†R H. = Relative Humidity
‡Some ears may show an increase in the amount of cerumen

In neither group was there any noteworthy change in the bacterial flora, or in the morphologic characteristics of the skin lining of the ear canal (see Table II)

Experiment C

Because of the conflicting information in the literature, this study was performed to determine how long a suspension of *Pseudomonas aeruginosa* introduced into the external ear canal of the cat, would persist and what morphologic skin changes would occur under conditions of high temperatures with humidifiers * The cool room temperature was maintained by use of a window air-conditioner† and the humidity lowered with a standard commercial type dehumidifier ‡

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*In this group are included the untreated control ears of other experiments performed at these same temperatures and humidities

EXPERIMENTAL PROCEDURES AND FINDINGS

Experiment A

Since no data could be found in the literature concerning the microbiologic flora of the normal external auditory canal of the cat, a limited study of the bacterial and mycologic flora was performed This provided some basis for comparison with the bacterial flora of the human ear and a control on the changes occurring after contamination with exogenous bacteria Cultures of the external auditory canals of 48 cats (96 ears) were taken after the animals had been maintained at ambient temperatures and humidities in the animal quarters

TABLE I—EXPERIMENT A

Bacteriologic Flora of the Normal Cat and Human External Auditory Canals

Microorganism	Cat (96 ears)	Human[11] (66 ears)
Pseudomonas group	0 0%*	0 0%*
Proteus group	1 0%	0 0%
Coli Aerogenes group	5 0%	6 1%
Micrococcus albus	79 2%	10 6%
Micrococcus albus hemolytic	65 6%	80 3%
Micrococcus aureus	5 2%	10 6%
Micrococcus aureus, hemolytic	7 3%	0 0%
Corynebacteria	1 0%	85 5%
Bacillus sp	5 2%	15 5%
Streptococcus α β, and γ types	0 0%	4 4%

*Percentage of ears in which microorganism was found

It is noteworthy that the bacterial flora of the cat is strikingly similar to that of the human external auditory canal (see Table I) The Gram-positive microorganisms are the most common endogenous bacteria on the skin of the normal external auditory canal Gram-negative bacilli are cultured

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*Walton Humidifier Model W-F

†Philco Air-Conditioner ¾ ton unit

‡Frigidaire Electric Dehumidifier

TABLE III —EXPERIMENT C

Survival of Pseudomonas (Undiluted) and Morphologic Changes Occurring in the External Auditory Canal of the Cat Under Conditions of High Temperatures and Humidities

AV T = 81° F　　Av R H = 92%

		Days Following Contamination																	
		0		2		4		6		8		10		12		15		18	
Cat	Ear	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact
38	R	N	Ps	D	4+	D	4+	R 1+ C 4+ X 2+	±			R 2+ C 4+ X 2+	4+			D C 3+	±		
38	L	N	Ps	R+	+	D	+	R ± C 2+	4+			R ± C +	±			D C 2+	*		
39	R	N	Ps	N	4+	N	4+	N	+			R ± C +	±			C +	*		
39	L	N	Ps	N	1+	N	2+	N	3+			N	±			N	*		
40	R	N	Ps	R+	4+	N	3+	R ± C 2+ X ±	+			R ± C 2+	3+			C 2+	*		
40	L	N	Ps	N	4+	N	4+	N	2+			N	2+			N	*		
41	R	N	Ps			R 2+ C 4+ X 4+	4+			R 3+ X 4+	1+			C 2+ X 4+ E 4+	4+			R + C 3+ E 3+	4+
42	L	N	Ps			N	4+			D	1+			N	±			N	*
43	R	N	Ps			D R 2+	1+			D	4+			D C +	±			N	*
44	L	N	Ps			N	4+			D C +	4+			N	4+			N	4+
45	R	N	Ps			D C 2+	1+			N	2+			D	4+			N	±

R = Erythema, C = Crusting X = Exudate E = Edema. N = Normal D = Dry * = No growth of Pseudomonas and high relative humidities (Av T 81° F , Av R H 92 per cent)

Five-tenths ml of an undiluted 24-hour broth suspension of Pseudomonas was instilled into the external ear canal The animals were examined and cultures of the ear canals taken at two or four-day intervals thereafter (with one exception) for 16 days

It may be seen in Table III that in all ears the Pseudomonas was still cultured on the tenth or twelfth day after contamination In four of the 11 ears the bacteria could be recovered on the fifteenth or sixteenth day

While not consistent in degree, there were some morphologic changes recorded at varying intervals in all ears Marked changes occurred in the skin lining the ear canals in four of the 11 ears Six of the ears had a dry appearance, erythema was noted in six, crusting was present intermittently in eight, exudate in three and severe edema in one At the conclusion of the experiment, six of the 11 ears were normal in appearance

Experiment D

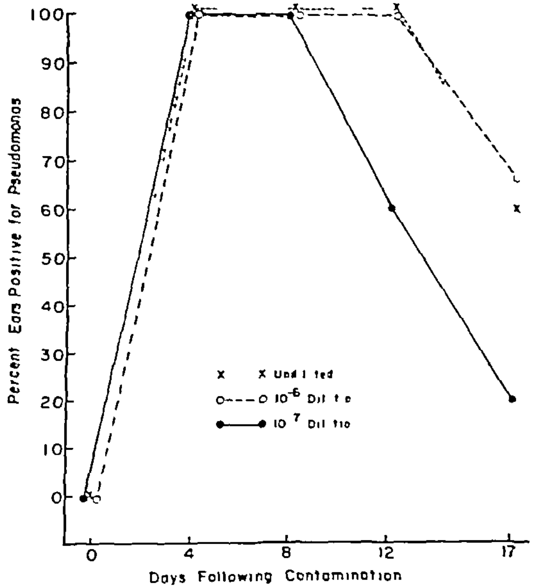
It has been demonstrated that an undiluted inoculum of Pseudomonas would survive for a period of weeks in the normal, untreated ear of the cat kept in a hot, moist environment It was considered desirable to determine whether diluted suspension of the organism would persist under similar conditions

Five-tenths ml of a 10^{-6} broth dilution of a 24-hour suspension of *Ps aeruginosa* was instilled into one ear of each of three cats, and 0 5 ml of a 10^{-7} dilution of the same organism was used to contaminate one ear of another group of five cats The contra-lateral ears served as controls The animals were housed in quarters in which the average temperature was 86° F , and the average relative humidity was close to 100 per cent Cultures were obtained at intervals for 17 days

It was noted in the first group (10^{-6} dilution) that there was a gradual diminution in the number of colonies grown, although the organisms persisted in all ears through the

One ear of each of three cats was contaminated with 0.5 ml of a 24-hour broth suspension of hemolytic *M aureus* and two animals with *Beta-type Streptococci* The contra-lateral ears of three of the animals were contaminated with 0.5 ml of a 10^{-6} dilution of *Pseudomonas aeruginosa,* and the remaining ears served as untreated controls for the experiment The animals were placed in an environment of high temperatures and high relative humidities (Av T 88° F , Av R H 96 per cent), and cultures were taken at intervals

Graph I
Experiment D
Comparison of Percent of Cat Ears Remaining Positive
After Contamination with Ps aeruginosa under Conditions
of High Temperatures and Humidities



In all three animals contaminated with *M aureus* there was a heavy growth on the first and second day There followed a rapid decrease in the number of organisms by the fourth day with all ears being free of the Micrococcus on the sixth

12th day and were present in two of the three contaminated ears on the 17th day.*

In all the contaminated ears of the second group (10^{-7} dilution), cultures remained positive on the 8th day while the organism was recovered on the 12th day in only three of the five ears. The Pseudomonas persisted in only one of the five ears on the 17th day. All control ears remained free of contamination (see Table IV).

TABLE IV.—EXPERIMENT D

Survival of Pseudomonas aeruginosa (Diluted) in the External Auditory Canal of the Cat Under Conditions of High Temperatures and Humidities

Av. T. = 85.5° F. Av. R.H. = 99.5%

Dilution	Cat	Days Following Contamination				
		0	4	8	12	17
10^{-6}	46A	Ps	4+	2+	3+	+
	49	Ps	4+	4+	2+	*
	50	Ps	4+	4+	2+	+
10^{-7}	25A	Ps	+	+	3+	+
	26A	Ps	4+	4+	*	*
	27A	Ps	4+	4+	*	*
	28A	Ps	4+	4+	3+	*
	29A	Ps	±	4+	4+	*

*No growth of Ps. aeruginosa.

When these two sets of data are compared and contrasted with the findings after the use of undiluted cultures, it is seen that the percentage of contaminated ears remain the same through the 8th day. The ears which received the more dilute suspension of bacteria appear to return to normal a little more rapidly than do those in which undiluted Pseudomonas was instilled (see Graph 1).

Experiment E

The purpose of this experiment was to determine the length of survival of undiluted cultures of *Micrococcus aureus* and *Beta-type Streptococci* in the healthy meatuses of the cat under conditions of high temperatures and humidities and contrast this with the known survival time of the Pseudomonas organism.

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*In one animal cross-contamination occurred in the control ear.

growth of the Pseudomonas was obtained on the first and second day in the ears in which it had been instilled (see Table VII)

Experiment H

In this experiment it was considered desirable to determine the effects of low temperatures (Av 61° F) and low relative humidities (Av 51 per cent) on the morphology and bacterial flora of the cat meatus Two cats (three ears) were observed for a period of seven to 15 days, while six cats (six ears) in a second group[*] were observed for 15 days

TABLE VII—EXPERIMENT G

Influence of Lipid Removal Trauma High Temperatures and High Relative Humidities on the Survival of Pseudomonas aeruginosa (10-6 Dilution) and Beta type Streptococcus in the External Auditory Canal of the Cat

Av T = 86° F Av R H = 98%

		Days Following Contamination		
Cat	Ear	0	1	2
25	R	Ps	4+	4+
25	L	Str	*	*
26	R	Str	*	*
26	L	Ps	4+	4+

*No growth.

TABLE VIII—EXPERIMENT H

Effects of Low Temperatures and Humidities Upon the Bacterial Flora and Morphology of the Cat External Auditory Canal

Av T = 61° F Av R H = 51%

Cats	Ears	Period of Observation	Bacterial Flora	Morphology
2	3	7 15 Days	Unchanged	Unchanged
6	6	15 Days	*	Unchanged

* = No cultures obtained

As noted in Table VIII, no morphologic changes were observed in either group, and the bacterial flora remained unchanged in the first group No cultures were obtained in the second group of animals

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[*] In these groups are included the untreated control ears of other experiments performed at these same temperatures and humidities

TABLE VI —EXPERIMENT F

Survival of Pseudomonas (Undiluted) and Morphologic Changes of Skin of the External Ear of the Cat Under *Conditions of Lipid Removal, Trauma and Elevated Temperatures and Humidities*

Av T = 85° F Av R H = 91%

		Days Following Contamination											
		0		2		4		7		11		15	
Cat	Ear	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact
28	R	N	Ps	R 3+ C 2+ X 2+	#	R + C 4+ X 3+	#	D C ±	#	D N	#	C ±	#
28	L	N	Ps	R 3+ C 3+ X 3+	#	R 2+ C 4+ X 2+	#	D C ±	#	D N	#	C ±	#
29	R	N	Ps	R 3+ C 2+ X 3+	#	D C +	#	D C 2+	#	N	#	N	#
29	L	N	Ps	R 2+ C 2+ X +	#	D R 2+ C 4+	#	D R + C 3+	#	C +		C 2+	#
30	R	N	Ps	R 2+ C + X 3+	#	R 2+ C 4+	#	D R 2+ C 4+	#	D C ±	#	C ±	#
30	L	N	Ps	R 4+ C 3+ X 3+	#	D C +	#	R 3+ C 4+	#	C ±	#	N	#
46	R	N	Ps	C 2+ X +	#	R 2+ C 2+ X 2+	#	*	*	R + C 3+ X 3+	#	C ±	#

= Growth of Pseudomonas R = Erythema C = Crusting X = Exudate D = Dryness N = Normal
* = No observations

growth of the Pseudomonas was obtained on the first and second day in the ears in which it had been instilled (see Table VII)

Experiment H

In this experiment it was considered desirable to determine the effects of low temperatures (Av 61° F) and low relative humidities (Av 51 per cent) on the morphology and bacterial flora of the cat meatus Two cats (three ears) were observed for a period of seven to 15 days while six cats (six ears) in a second group* were observed for 15 days

TABLE VII —EXPERIMENT G

Influence of Lipid Removal. Trauma High Temperatures and High Relative Humidities on the Survival of Pseudomonas aeruginosa (10^{-6} Dilution) and Beta type Streptococcus in the External Auditory Canal of the Cat

Av T = 86 F Av R.H = 98%

		Days Following Contamination		
Cat	Ear	0	1	2
25	R	Ps	4+	4+
25	L	Str	*	*
26	R	Str	*	*
26	L	Ps	4+	4+

*No growth.

TABLE VIII —EXPERIMENT H

Effects of Low Temperatures and Humidities Upon the Bacterial Flora and Morphology of the Cat External Auditory Canal

Av T = 61° F Av R.H. = 51%

Cats	Ears	Period of Observation	Bacterial Flora	Morphology
2	3	7-15 Days	Unchanged	Unchanged
6	6	15 Days	*	Unchanged

* = No cultures obtained.

As noted in Table VIII no morphologic changes were observed in either group and the bacterial flora remained unchanged in the first group No cultures were obtained in the second group of animals

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*In these groups are included the untreated control ears of other experiments performed at these same temperatures and humidities

TABLE VI—EXPERIMENT F

Survival of Pseudomonas (Undiluted) and Morphologic Changes of Skin of the External Ear of the Cat Under Conditions of Lipid Removal, Trauma and Elevated Temperatures and Humidities

Av T = 85° F Av R H = 91%

		Days Following Contamination											
		0		2		4		7		11		15	
Cat	Ear	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact
28	R	N	Ps	R 3+ C 2+ X 2+	#	R + C 4+ X 3+	#	D C ±	#	D N	#	C ±	#
28	L	N	Ps	R 3+ C 3+ X 3+	#	R 2+ C 4+ X 2+	#	D C ±	#	D N	#	C ±	#
29	R	N	Ps	R 3+ C 2+ X 3+	#	D C +	#	D C 2+	#	N	#	N	#
29	L	N	Ps	R 2+ C 2+ X +	#	D R 2+ C 4+	#	D R + C 3+	#	C +		C 2+	#
30	R	N	Ps	R 2+ C + X 3+	#	R 2+ C 4+	#	D R 2+ C 4+	#	D C ±	#	C ±	#
30	L	N	Ps	R 4+ C 3+ X 3+	#	D C +	#	R 3+ C 4+	#	C ±	#	N	#
46	R	N	Ps	C 2+ X +	#	R 2+ C 2+ X 2+	#	*	*	R + C 3+ X 3+	#	C ±	#

= Growth of Pseudomonas R = Erythema C = Crusting X = Exudate D = Dryness N = Normal
* = No observations.

growth of the Pseudomonas was obtained on the first and second day in the ears in which it had been instilled (see Table VII)

Experiment H

In this experiment it was considered desirable to determine the effects of low temperatures (Av 61° F) and low relative humidities (Av 51 per cent) on the morphology and bacterial flora of the cat meatus Two cats (three ears) were observed for a period of seven to 15 days, while six cats (six ears) in a second group* were observed for 15 days

As noted in Table VIII, no morphologic changes were observed in either group, and the bacterial flora remained unchanged in the first group No cultures were obtained in the second group of animals

TABLE VII—EXPERIMENT G

Influence of Lipid Removal Trauma High Temperatures and High Relative Humidities on the Survival of Pseudomonas aeruginosa (10^{-6} Dilution) and Beta type Streptococcus in the External Auditory Canal of the Cat.

Av T = 86° F   Av R H = 98%

		Days Following Contamination		
Cat	Ear	0	1	2
25	R	Ps	4+	4+
25	L	Str	*	*
26	R	Str	*	*
26	L	Ps	4−	4+

*No growth.

TABLE VIII—EXPERIMENT H

Effects of Low Temperatures and Humidities Upon the Bacterial Flora and Morphology of the Cat External Auditory Canal

Av T = 61° F   Av R.H = 51%

Cats	Ears	Period of Observation	Bacterial Flora	Morphology
2	3	7 15 Days	Unchanged	Unchanged
6	6	15 Days	*	Unchanged

* = No cultures obtained

---

*In these groups are included the untreated control ears of other experiments performed at these same temperatures and humidities

Experiment J

Undiluted suspensions of *Pseudomonas aeruginosa* have been shown to persist and morphologic changes have occurred in the external auditory canal of the cat for long periods under conditions of high temperatures and humidities This experiment was designed to determine whether *Ps aeruginosa* would similarly persist and morphologic changes occur in the cat meatus in a cooler and drier environment

The external auditory canals of five cats (five ears) were contaminated with 0 5 ml of an undiluted 24-hour broth suspension of *Ps aeruginosa* The animals were then placed in an environment of lowered temperatures and humidities (Av T 56° F , Av R H 50 per cent) Cultures of all ears were taken at various intervals for 17 days

In all of the contaminated ears, the organisms were recovered in large numbers through the eighth day, but a rapid reduction occurred thereafter, so that only two ears showed any growth on the seventeenth day Minimal skin changes were observed on the eighth day with one exception, and most of the changes had subsided by the fourteenth day (see Table IX)

Experiment K

It has been shown that morphologic changes are less after Pseudomonas contamination in a lowered environmental temperature and humidity, but that there is little effect upon the persisting exogenous bacterial flora To observe the changes which occur to the skin of the cat meatus after lipid removal, trauma and the instillation of *Pseudomonas aeruginosa* under cool, dry conditions the following experiment was conducted

Three cats (six ears) were contaminated with 0 5 ml of an undiluted 24-hour broth suspension of *Ps aeruginosa* after trauma and removal of the surface lipids The animals were placed in a cool, dry environment (Av T 58° F , Av R H 51 per cent) for a period of 15 days Cultures of the secretions of the ear canal and examinations of the skin lining the canals were made at two, three or four-day intervals

In all of the ears, the skin of the ear canal showed varying degrees of dryness, crusting, erythema and exudate on the

TABLE IX—EXPERIMENT I

Survival of Ps aeruginosa (Undiluted) and Morphogic Changes in the External Auditory Canal of the Cat Under Conditions of Low Temperatures and Humidities

Av T 56° F Av R H 50%

		Days Following Contamination											
		0		4		8		12		14		17	
Cat	Ear	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact
45A	L	N	Ps	C +	4+	N	4+	N	4+	N	+	N	+
37	R	N	Ps	C ± X 4+	4+	C + X 2+	1+	C ± R +	4+	R +	4+	N	2+
38A	L	N	Ps	D	4+	C ±	4+	N	+	N	+	N	*
39A	R	N	Ps	D	4+	N	4+	N	2+	N	3+	N	*
40A	L	N	Ps	N	4+	N	1+	N	±	N	*	N	*

* = No growth of Ps aeruginosa N = Normal D = Dry X = Exudate R = Erythema.

TABLE X—EXPERIMENT K

Survival of Pseudomonas (Undiluted) and Morphologic Changes Produced in the External Auditory Canal of the Cat Under Conditions of Lipid Removal, Trauma, Low Temperatures and Humidities

Av T = 58° F Av R.H = 51%

		Days Following Contamination											
		0		2		4		7		11		15	
Cat	Ear	Morph	Bact	Morph	Bact	Morph	Bact	Morph	Bact.	Morph	Bact.	Morph	Bact.
32A	R	N	Ps	R 4+ C 2+ X 3+	4+	R 4+ C 4+ X 3+	4+	D R 2+ C 4+	4+	C ±	4+	C ±	4+
32A	L	N	Ps	R 2+ C 2+ X 3+	4+	R 4+ C 4+ X 4+	4+	D R 3+ C 4+	4+	C +	4+	C ±	4+
33	R	N	Ps	R 3+ C 2+ X 2+	4+	D C +	+	D C +	*	N	*	D	*
33	L	N	Ps	R 3+ C 3+ X ±	4+	D R 2+ C 2+	4+	D C ±	4+	D	4+	N	2+
34	R	N	Ps	R 3+ C 3+ X +	4+	D C +	4+	C +	4+	D	4+	N	+
34	L	N	Ps	R 2+ C 2+ X ±	4+	C +	4+	D C ±	4+	R ±	4+	N	4+

R = Erythema. C = Crusting X = Exudate D = Dry N = Normal * = No growth second day Morphologic changes were strikingly decreased in four of the ears on the fourth day, were less in all ears on the seventh day and minimal findings were present on subsequent examinations On the other hand, Pseudomonas colonies were cultured from all ears through the fourth day and from seven of the eight ears through the balance of the experiment (see Table X)

DISCUSSION

The inadequacy of the techniques for obtaining precise serial estimates of the number and variety of the bacteria implanted into the animal external auditory canal is recognized Preliminary studies were performed in an effort to find more satisfactory methods, but the peculiar and highly variable anatomical configuration of the meatus made these more accurate procedures clinically and experimentally impractical In an effort to reduce possible errors in interpretation, experiments were set up in duplicate and, although not always included in the data, controls were introduced in all the studies

It was found necessary to perform a survey of the bacterial flora in the normal external auditory canal of the cat in order to determine whether the organisms which are cultured from acutely infected human ear canals were present in the endogenous flora of these animals Upon comparison of the flora of the human and animal ear canals, there is noted a striking similarity Conspicuously absent is the pseudomonas group of bacteria in the flora of both humans and animals This observation is of particular interest since *Pseudomonas aeruginosa* has been shown to be the exogenous organism most frequently cultured from acute diffuse external otitis

Because numerous investigators have demonstrated that normal intact human skin in other parts of the body rapidly eliminates implanted exogenous bacteria in a matter of minutes or hours, it was surmised that this same phenomenon would occur in the meatus of the experimental animal On the contrary, *Ps aeruginosa* introduced into the external auditory canal of the cat exposed to a hot, humid environment persisted for as long as 18 days This finding substantiates our previous observations.[32] The results of these experiments duplicate the experience of the otologists in tropical and subtropical regions, who report the persistence for indefinite periods of pseudomonas organisms in the meatus of patients with "cured" diffuse external otitis. They are not in agreement with the observations of Shelley and Perry,[28] who were unable to recover *Ps. aeruginosa* which had been introduced one week previously into the ear canals of human subjects.

It was anticipated that *Ps. aeruginosa* in dilute suspensions would survive for shorter periods when introduced into the healthy cat meatus. The diluted suspensions of *Ps. aeruginosa* appeared to increase to a maximum just as rapidly as the undiluted cultures for the first six to eight days, while the undiluted cultures seem to reduce in numbers more rapidly thereafter. Diluting the cultures did not appear to exert an appreciable influence upon the rapidity with which the bacteria were completely eliminated. The results appear to confirm the theory that bacterial infection of the ear canal is not necessarily caused by overwhelming contamination, but rather that only a few virulent organisms implanted on a fertile skin substrate will rapidly multiply in the ear canal and institute infection in a susceptible individual.

In addition to the persistence of the contaminating bacteria, gross morphologic changes (crusting, erythema, edema and exudate) occurred after the introduction of *Ps. aeruginosa*. The changes were not present in all the infected animals and they varied in severity, thus simulating the clinical findings in human external otitis. These observations conflict with previous studies[30, 31, 32] in which we, as well as other investigators, were unable to produce disease of the external ear or only minimal microscopic changes in the skin by the mere instillation of fungi or bacteria. This difference may be a consequence of uncontrolled factors, such as the virulence of the contaminating organism and individual susceptibility of the experimental animal.

Although no experiments were designed to test the virulence of pseudomonas cultures, it was noted that frequent subculturing of the stock strains resulted in attenuated organisms which failed to survive or produce morphologic changes in the cat ear, consequently, it was found necessary to discard some strains of *Ps aeruginosa* after a period of growth on artificial media

Individual differences in susceptibility of the experimental animals were also demonstrated throughout the experiments Some animals appeared to be highly sensitive to the infecting bacteria, with consequent prolonged survival of the organisms and severe morphologic changes Other animals used in these studies were apparently resistant regardless of environmental conditions or combinations of factors Further studies are desirable concerning virulence and susceptibility of both animals and humans to *Ps aeruginosa*

Our observations failed to substantiate the hypothesis that exposure of our experimental animals to hot, moist atmospheric conditions would make the skin of the ear more susceptible to infection with exogenous organisms [11] Gross morphologic changes or alterations in the endogenous bacterial flora of the uncontaminated external auditory canal did not occur during exposure of cats to markedly elevated or moderately lowered temperatures and humidities, however, when cats with infected ears were transferred from a hot, humid environment to a cool, low-humidity room, no startling reduction in the number of bacteria was noted, although some improvement of the skin morphology occurred [29]

High temperatures and high relative humidities were not found to be the sole factors responsible for the prolonged survival of implanted exogenous bacteria or the concomitant skin changes, since the organisms were shown to persist in some animals for long periods at low temperatures and humidities Some of the data, however, would indicate that at high temperatures and humidities the growth of the *Ps aeruginosa* was more luxuriant than when the animals were kept in a cool, dry environment

Various reports have shown that there is a distinct difference in the ability of healthy, intact skin to eliminate bacteria belonging to the Gram-positive and Gram-negative categories In our series of experiments, as in other skin areas, it was noted that streptococci failed to persist even for very short periods The suspension of coagulase-positive *M aureus* was not eliminated as rapidly as the streptococci, but much more rapidly and completely than any of the Gram-negative bacilli tested A warm, moist atmosphere did not appear to be conducive to the survival of the Gram-positive bacteria, nor did removal of the fatty covering or trauma contribute to persistence of the organism

In this study it was not possible to test a sufficiently large number of animals, or to control the many variables in such a manner that statistical evaluation of the data could be performed Should further investigations of the influence of temperature, humidity, trauma and lipid removal on the survival of exogenous organisms be undertaken, then the number of animals used should be increased or the number of variables reduced to make statistical studies possible

CONCLUSIONS

The endogenous bacterial flora of the healthy cat meatus is very similar to that of the normal human external auditory canal

Elevated or lowered temperatures and humidities do not alter the endogenous flora or produce any change in the morphology of the skin of the cat ear canal

Exogenous Gram-negative bacteria, particularly the *Ps aeruginosa,* will survive for prolonged periods in the external auditory canal of the cat at low or high temperatures and humidities The Gram-positive organisms, *i e , Beta-hemolytic Streptococcus* and *M aureus,* are eliminated after a relatively short period

Suspensions of *Ps aeruginosa* introduced into susceptible cat ear canals will produce morphologic skin changes at high temperatures and humidities

Some of the data suggest that, in a cool, low-humidity environment, there may be less luxuriant bacterial growth, a shorter survival time and fewer morphologic changes after instillation of Gram-negative bacilli

Trauma to the skin of the cat external auditory canal and removal of the surface lipids did not appear to alter the survival time of the exogenous organisms

The concentration of organisms instilled into the cat ear (within the range tested) is not an important factor in the length of survival of this organism or the severity of the morphologic changes produced

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STUDIES OF FACTORS CONSIDERED RESPONSIBLE FOR DISEASES OF THE EXTERNAL AUDITORY CANAL[*]

II Evaluation of Temperature and Humidity as They Influence the Amount of Ether-Soluble Substances in the External Auditory Canal

ELIZABETH S BAUMANN, B A ,
CARL F GESSERT, Ph D ,
and
BEN H SENTURIA, M D ,

St Louis, Mo

INTRODUCTION

It is generally accepted that the highest incidence of diffuse external otitis occurs in hot, humid climates, while there are comparatively few cases observed in cool, dry environments It has been suggested that an alteration of the lipid skin cover, caused by conditions of high temperature and high humidity, may play a role in the production of this disease[1]

Studies have been made of the effects of temperature and moisture on the lipid covering of the skin of various other parts of the body,[2-9] but there is a paucity of data pertaining to these effects on the lipids of the skin of the ear canal[10] Although determinations were previously made in this laboratory on the amounts of ether-soluble substances (ESS)[†] which are found in the external auditory canals of various groups of humans,[11] none of the data were obtained under controlled environmental conditions The present experiments, therefore, were designed to measure ESS in the external auditory

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[*] From the Washington University School of Medicine Department of Otolaryngology St. Louis Mo

[†] Ether-soluble substances (ESS) are the lipids extracted with ether *from cerumen specimens*

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canals of animals, which could be maintained in environments of controlled temperature and humidity In this way, an evaluation could be made of the effects of temperature and humidity on the lipid film of the skin of the cartilaginous meatus

LITERATURE REVIEW

Some workers are convinced that the lipid film on the surface of the skin acts as an important barrier in preventing the extension of bacteria into or through the epidermis The lipid cover has been shown to have bactericidal and fungistatic properties[12-17] According to Rebell et al,[17] Gram-negative bacilli survived for much longer periods on skin from which the lipids were removed by thorough washing with organic solvents than on skin on which the lipid cover had been left intact Arnold and his co-workers[18] found that a coating of grease or dirt on the skin of hands allowed such bacilli to remain viable for long periods of time The findings of these two investigators are not necessarily contradictory since in one case the skin lipids are removed, and in the other case they are covered up so that they do not come in contact with the bacteria

The influence of environmental temperatures and skin moisture on the amount and distribution of lipids on the skin surface has been considered by many investigators[2-9] The theory has been advanced that at high temperatures and on moist skin the sebum may become fluid[6-9] and in this manner fail to provide a protective cover[3]

Mole[18] and Blank[19 20] have demonstrated that the stratum corneum will take up moisture from an environment having a high relative humidity Blank showed that cornified epithelium absorbed increasing amounts of moisture, particularly at relative humidities above 80 per cent It is conceivable, therefore, that when exposed to high humidities, the keratin in and around the orifice of the apo-pilosebaceous unit absorbs moisture, thereby swelling and causing a decreased flow of lipids to the skin surface[21-23]

METHODS AND TECHNIQUES

Animals. The cat and pig have been shown to have apocrine and sebaceous glands in the skin of the ear canal similar to those of the human.[26-28] The cat was chosen as the most suitable and available experimental animal. The difficulty of handling the cat, however, made it desirable to use in some of these experiments a more tractable animal, such as the rabbit, which has in the skin of its external ear canal numerous sebaceous but no apocrine glands. In two experiments cats and rabbits were used simultaneously, so that data from these two species could be compared.

Maintenance. Experimental animals were housed in individual metal cages, and all were offered a balanced diet.

Experimental Rooms. In the hot room the desired temperature was achieved by use of electric heaters controlled by thermostat,* which supplemented the centrally supplied steam heat. An automatically controlled humidifier† maintained humidities within the planned range. Conditions of low temperature and humidity were achieved in the cool room by use of a room air-conditioner‡ and a dehumidifier.§

Anesthesia. It was frequently necessary to anesthetize the cats. This was done by intrathoracic injection of pentobarbital sodium, approximately 12 mg. per pound of body weight. A few cats were anesthetized by intraperitoneal injection, but the intrathoracic route was found to be more satisfactory, in that the animals were subdued with less struggle and recovery was much faster, usually occurring within four to six hours. When no anesthetic was used, the cats were managed by wrapping them in a large square of heavy denim cloth, and the rabbits were restrained in a wooden box designed for that purpose.

Collection and Analysis of Specimens. Specimens for the determination of total ESS were obtained by wiping the cartilaginous meatus in a prescribed manner with two cotton swabs moistened with ether[11] The swabs were extracted with redistilled ether in a micro-Soxhlet apparatus and the amounts of ESS were determined by a colorimetric method adapted to micro-scale[29]

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*Two Chromolon electric heaters thermostatically controlled by a Mercoid Switch.

†Walton Humidifier Model W.F.

‡General Electric Room Conditioner ¾-ton.

§Frigidaire portable dehumidifier.

Samples for the determination of the percentages of lipid and protein were collected and analyzed by methods previously described[30]

In all experiments a casual* specimen was taken from each ear to be studied For those experiments in which a zero-day† specimen was obtained, the order of the procedure was *a* Casual specimen taken, *b* ear canal and auricle cleansed with three cotton swabs moistened with ether, *c* zero-day specimen taken

EXPERIMENTAL PROCEDURES AND FINDINGS

Preliminary Experiments on Cats and Rabbits

Several pilot studies were conducted to examine the ear secretions of the animals without control of environmental temperature and humidity The normal (ambient) animal room temperatures and humidities were allowed to prevail

Experiment A

The percentage of protein and lipid in the cerumen of cats was investigated Casual specimens were collected from both ears of two cats and the ears were cleaned with ether-moistened swabs Fresh samples‡ were taken at two and 12 days after cleaning

As shown in Table I, the percentage of lipid in the first fresh samples (taken after cleaning) was higher than in the casual cerumen, while the percentage of protein was generally lower By the twelfth day the percentage composition of the cerumen of each cat ear tended to revert to the composition of the corresponding casual specimens In these characteristics, the findings in cats were similar to those for humans, as reported by Chiang et al.[31]

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*Casual specimens are the samples obtained from the unprotected skin surfaces of the ear canal at the beginning of the period of observation without previous cleansing or treatment of the canal

†Zero-day refers to the initial day of any series of observations Specimens designated as zero day samples were collected immediately after cleansing the ear canal

‡A fresh sample is a specimen collected during the period of observation at any time after zero-day

Experiment B

The amounts of ESS obtained from the external auditory canals of cats and rabbits were compared. Casual and zero-day specimens were taken from one ear each of two cats and two rabbits. At intervals of four, eight and 15 days, specimens were obtained from the same ears.

The data in Table II indicate that one can expect the same order of magnitude in the amounts of ESS obtained from the ear canals of cats and rabbits. These amounts are generally larger than the amounts obtained from humans, as reported by Chiang et al.[11] As previously observed with humans, by the fifteenth day replacement totals (RT)* exceeded their respective casual amounts.[11]

TABLE I.—EXPERIMENT A

Percentages of Lipid and Protein in Cat Cerumen

		Casual Specimens		Day of Collection			
				2		12	
Cat	Ear	Lipid	Protein	L	P	L	P
2	R	46.9	22.9	54.8	14.9	41.3	15.1
2	L	47.5	30.6	56.2	15.8	46.8	19.9
3	R	32.1	32.7	53.0	20.6	32.4	24.3
3	L	36.3	41.8	44.3	38.1	28.4	39.1

Despite the histological differences of the skin of the cat and rabbit meatus, the findings here regarding average daily replacements (ADR)† and RT's are similar in these two species. The absence of apocrine glands in the skin of the rabbit did not appear to influence the amount of ESS recovered in these few ear canals.

Experiment C

Because the cleansing procedure used on zero-day might introduce an uncontrolled factor either by being traumatic to the skin of the ear canal or by influencing the delivery of lipids to the surface, this experiment was designed to determine whether or not the cleansing had any effect on the amounts of ESS subsequently obtained.

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*Replacement total (RT) at any given time is the total amount of ESS that has been extracted from all the fresh specimens collected by that time from a single ear. This does not include zero-day amount.

†The average daily replacement (ADR) is a measure of the rate of lipid renewal on the skin surface during any interval between successive collections. It is calculated by dividing the amount of ESS in a fresh specimen by the number of days in the interval since the preceding collection.

In one ear of each of two rabbits a casual specimen was obtained, the canal was thoroughly cleansed, and a zero-day specimen was taken. In the contra-lateral ears casual specimens were taken, but no cleansing was performed and no zero-day specimens were obtained. At intervals of three seven and 14 days, specimens were taken from all ears (see Table III).

TABLE II.—EXPERIMENT B

Ether-soluble Substances in Cat and Rabbit Cerumen. A Comparison in Terms of Average Daily Replacements and Replacement Totals (Expressed in Milligrams)

Animal and Ear	Casual Amount	Zero-day Amount	Days After Cleaning 4		8		15	
			ADR*	RT†	ADR	RT	ADR	RT
Cat 90 L	15.3	1.3	1.4	5.4	1.3	10.5	1.0	17.8
Cat 91 R	10.8	1.2	1.3	5.0	1.0	8.9	0.9	15.1
Rabbit 59 R	11.8	0.4	1.7	6.8	2.3	15.9	1.6	27.1
Rabbit 60 L	10.2	1.2	1.4	5.7	3.0	12.1	2.4	29.0

*Average Daily Replacement
†Replacement Total (does not include zero day amount)

In the rabbit, thorough cleansing of the ear canal did not appear to influence the amounts of ESS which were obtained from the third day on. The technique for taking casual specimens evidently constituted a sufficient cleansing of the ear canal so that the additional cleansing had no effect.

Experiments on Cats and Rabbits Under Controlled Environmental Conditions

Experiment D

A comparison was made of the amount of ESS obtained from the ear canals of cats and rabbits kept under controlled environmental conditions.

Casual specimens were taken from both ears of two cats and two rabbits, the animals were kept in a cool, dry room for seven days, and then in a hot, humid room for seven days Specimens of ESS were taken on days 3, 5, 7 and 10, 12, 14 By measuring the amounts obtained on days 5, 7, 12, and 14,* it was possible to compare the data for two 2-day periods, under both environmental conditions (see Table IV)

Under the experimental conditions employed, the average amounts of ESS obtained from the ears of cats and of rabbits were somewhat greater when the animals were kept in the hot, humid room (12th and 14th days) than when they were in the cool, dehumidified room (5th and 7th days) †

TABLE III—EXPERIMENT C

Amounts of Ether soluble Substances (in Milligrams) Found in Rabbit Ear Canals, with or without a Cleansing Procedure

			Day of Collection			
Rabbit	Ear	Casual	Zero-day	3	7	14
65	R	6 0*	0 5	6 6	12 3	11 8
65	L	5 4		6 7	12 3	5 6
66	R	6 4		8 9	6 0	4 1
66	L	7 7*	2 3	8 5	4 2	4 3

*After casual specimen was taken ear was cleaned with 3 cotton swabs dipped in ether

As in Experiment B, no difference was observed between the average amount of ESS obtained from the ears of cats and rabbits when both groups were maintained in the same environmental conditions

Experiment E

In order to cancel any undetermined effects that order of exposure and the factor of time might have had on the data of Experiment D, it was decided to reverse the environments with half of the animals

Casual specimens were taken from one ear each of eight rabbits For a period of 11 days, half of the animals were kept in a hot, humid room and the other half in a cool, low-humidity room. Then the animals were interchanged for a similar period of time. Specimens for total ESS were taken on days 7, 9, 11 and 18, 20, 22. By determining the amounts of ESS obtained on days 9 and 11 in one environment, and on *days 20 and 22 in the other,* data were obtained for two 2-day* periods of accumulated secretions in both environments (see Table V).

---

*Specimens from days 3 and 10 were not determined as they represented 3-day intervals

†The significance of these differences was not evaluated statistically because of the limited number of animals

TABLE IV—EXPERIMENT D

The Amounts of Ether soluble Substances (in Milligrams) Obtained from the Ear Canals of Cats and Rabbits Kept in Environments of Controlled Temperature and Humidity*

Animal	Ear	Day of Collection 5 Cool dry room†	 7	 12 Hot, humid room‡	 14
Cat 1	R	6.7		5.8	6.1
Cat 1	L	5.0	5.7	5.6	7.4
Cat 2	R	5.7	7.1	6.6	9.1
Cat 2	L	8.0	6.5	8.0	11.8
Mean ESS		6.39		7.55	
Rabbit 3	R	6.3	6.1	9.2	7.1
Rabbit 3	L	4.8	5.2	7.6	6.6
Rabbit 4	R	4.4	4.4	6.4	5.3
Rabbit 4	L	5.1	7.3	7.5	5.7
Mean ESS		5.45		6.93	

*Dry and wet bulb temperatures were measured daily. Relative humidity was read from Relative Humidity Tables printed by Taylor Instrument Companies, Rochester, N. Y.

†Temperature Av. 71° F (range 69-74° F) Relative Humidity Av. 70% (range 64-74%)

‡Temperature Av. 85° F (range 84-88° F) Relative Humidity Av. 95% (range 93-98%)

A comparison was made between the data obtained from each rabbit ear during the time that the animal was in the hot, humid environment and that obtained from the same ear when the rabbit was in the cool, low-humidity room. When the data were compared, no significant difference was found between the amounts of ESS obtained in the two environments, under the experimental conditions employed.† The lack of a real difference in the amounts obtained was also reflected in the closeness of the means of 2-day accumulations in the two environments, *i.e.*, 6.29 and 6.53 (see Table V).

---

*Specimens on days 7 and 18 were not considered because they represented amounts accumulated for 7-day periods.

†Probability was much greater than 0.1 by the Wilcoxon signed-rank test for matched samples.[22]

Experiment F

Since it seemed possible that the effect of a particular environment might not be immediately apparent, it was considered desirable to expose the animals to each environment for a longer period of time than had been done in Experiment E

Cats were used in this study, whereas rabbits had been used in Experiment E Casual specimens were taken from both

TABLE V—EXPERIMENT E

The Amounts of Ether soluble Substances (in Milligrams) Obtained from *Ear Canals of Rabbits Kept in Environments* of Controlled* Temperature and Humidity †

Ear	Day of Collection			
	9	11	20	22
	Hot humid room‡		Cool, dry room§	
5 R	5 5	5 1	4 9	4 4
6 L	6 6	6 3	8 9	6 2
7 R	6 7	7 0	6 9	5 9
8 L	9 2	6 7	7 3	6 2
	Cool dry room§		Hot humid room‡	
9 R	7 9	5 9	5 5	5 0
10 L	6 6	5 6	8 1	6 9
11 R	7 7	5 9	8 4	4 1
12 L	5 6	4 8	7 7	5 6
Overall means of ESS for 2-day periods				
Cool, dry room				6 29 mg
Hot, humid room				6 53 mg

---

*Order of environmental exposure was reversed with half of the animals

†See first footnote of Table IV

‡Temperature Av 83° F (range 79-85° F) Relative humidity Av 91% (range 80-96%)

§Temperature Av 66° F (range 60-69° F) Relative humidity Av 56% (range 38-70%)

ears of each of six cats, which were divided into two equal groups, one being placed in a hot, humid room and the other in a cool, low-humidity room Fresh specimens were taken at the end of each week for three weeks, then the two groups of cats were interchanged, and specimens were taken weekly for another three weeks The data which were obtained on the amounts of ESS in all fresh specimens are shown in Table VI

The data were examined in two ways In one test, the data from only one ear of each of the six animals were considered and in the other the data from both ears were added and used together. As in Experiment E the hot, humid room data for each animal were compared with the cool, dry room data for the same animal. The overall means of the amounts of ESS obtained per ear in the period of a week were 14.5 mg in the cool dry room and 13.1 mg in the hot, humid room. In both methods of examining the data, no significant difference was found between the amounts of ESS obtained in the two environments under the experimental conditions employed.*

TABLE XI.—EXPERIMENT F

The Amounts of Ether-soluble Substances (in Milligrams) Obtained from the Ear Canals of Cats Kept in Environments* of Controlled Temperature and Humidity†

Ear	Day of Collection					
	7	15	22	29	36	43
	Hot humid room‡			Cool dry room§		
14 R	23.6	14.2	16.1	15.0	17.5	20.6
14 L	12.8	o	10.4	11.9	15.5	14.9
15 R	16.5	15.3	15.9	20.1	12.2	12.6
15 L	8.2	6.6	12.0	20.9	18.7	21.7
18 R**	(14.3)	(16.5)	(15.2)	o	(40.0)	o
18 L	16.5	13.2	16.6	23.1	18.1	21.4
	Cool dry room§			Hot humid room‡		
13 R	4.8	9.7	7.5	9.0	8.9	14.0
13 L	11.8	8.8	8.7	6.9	8.5	14.8
16 R	16.8	14.2	13.4	10.2	10.8	16.1
16 L	13.6	14.8	14.7	13.9	15.5	20.4
17 R	14	17.6	9.8	5.8	13.5	9.0
17 L	14.8	12.4	11.0	11.9	14.0	19.2

Overall means of ESS for weekly periods

Cool dry room	14.5 mg
Hot humid room	13.1 mg

*Order of environmental exposure was reversed with half of the animals.

†See first footnote for Table IX.

‡Temperature: Av 85 F (range 82-88 F). Relative humidity: Av 92% (range 77-100%).

§Temperature: Av 64 F (range 61-70 F). Relative humidity: Av 58% (range 37-74%).

oSpecimen accidentally destroyed.

**None of the data pertaining to 18-R were taken into account because the data for this ear were incomplete.

---

*Probability was greater than 0.1 by the Wilcoxon signed-rank test.[22]

Experiment F

Since it seemed possible that the effect of a particular environment might not be immediately apparent, it was considered desirable to expose the animals to each environment for a longer period of time than had been done in Experiment E

Cats were used in this study, whereas rabbits had been used in Experiment E Casual specimens were taken from both ears of each of six cats, which were divided into two equal groups, one being placed in a hot, humid room and the other in a cool, low-humidity room Fresh specimens were taken at the end of each week for three weeks, then the two groups of cats were interchanged, and specimens were taken weekly for another three weeks The data which were obtained on the amounts of ESS in all fresh specimens are shown in Table VI

TABLE V—EXPERIMENT E

The Amounts of Ether soluble Substances (in Milligrams) Obtained from Ear Canals of Rabbits Kept in Environments* of Controlled Temperature and Humidity †

	Day of Collection			
	9	11	20	22
Ear	Hot humid room‡		Cool dry room§	
5 R	5 5	5 1	4 9	4 4
6 L	6 6	6 3	8 9	6 2
7 R	6 7	7 0	6 9	5 9
8 L	9 2	6 7	7 3	6 2
	Cool dry room§		Hot humid room‡	
9 R	7 9	5 9	5 5	5 0
10 L	6 6	5 6	8 1	6 9
11 R	7 7	5 9	8 4	4 1
12 L	5 6	4 8	7 7	5 6

Overall means of ESS for 2 day periods

Cool, dry room	6 29 mg
Hot, humid room	6 53 mg

*Order of environmental exposure was reversed with half of the animals

†*See first footnote of Table IV*

‡Temperature Av 83 F (range 79-85° F) Relative humidity Av 91% (range 80-96%)

§Temperature Av 66° F (range 60-69° F) Relative humidity Av 56% (range 38-70%)

The data were examined in two ways In one test, the data coating which is present on the skin surface in the external ear canals of the rabbit and cat

It is of interest that the average amounts of ESS that were obtained from the external ear canals of cats and rabbits which were kept in the same environment did not appear to differ, even though there are notable histological differences in the skin of the ear canals of the two species The presence of apocrine glands in the skin of the cat meatus and their absence in the rabbit had no measurable effect on the quantities of ESS found

CONCLUSION

The quantity of lipid material (measured as ESS) which is found in the ear canal of the cat or rabbit is not significantly different whether the animal is kept in a hot, humid environment, or in a relatively cool, low-humidity room

ACKNOWLEDGMENTS

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DISCUSSION

A completely satisfactory method for collecting specimens which contain all of the ether-soluble matter that is present in an ear canal at a given time has not yet been devised In view of the variation in size and anatomical configuration of the external auditory canal that prevails from one animal to another, there is, very likely, some variation in the degree of completeness with which the total ESS present in a meatus are collected with our ether-moistened swab technique

Tests have been made to determine the *feasibility of* collecting the lipid matter by instilling several successive, measured portions of organic solvent, *i e*, ether and ethanol, into the ear canal, recovering the solvent solution with a syringe and a small piece of flexible tubing, then measuring the lipid in these solutions It was found, however, that in the cat, ether used in this manner acted as a strong irritant, whereas ethanol was unsatisfactory as a solvent Although the swab method of collecting specimens of ESS was far from being ideal, it seemed to be the more satisfactory for the purposes of these studies

The amount of lipid (ESS) which was found in the meatus in both cats and rabbits revealed neither an increase nor decrease when the animals were kept in a hot, humid environment, as compared with a cool, low-humidity environment The protected position of the external auditory canal may afford a degree of insulation sufficient to prevent any large fluctuations in air temperature in the meatus, and, therefore, also may prevent any change in the physical characteristics of the skin surface film It is also conceivable that even though the viscosity of the skin surface lipids may be lowered by an increased temperature, the anatomical configuration of the cartilaginous meatus would prevent the lipids from flowing to the perimeatal regions

It is still possible that environmental temperature and humidity do have an important role in determining susceptibility of the skin of the auditory canal to infection It appears, however, from our data, that these factors do not exert their influence through a regulation of the amount of lipid

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THE GOULD AWARD

The Gould Award is presented annually for outstanding research in laryngology to encourage and reward fundamental investigations in this field

The International Committee for the Gould Award announces the selection of the recipient for the year 1958 Prof FumioNakamura, M D, Kyoto Prefectural Medical College, Kyoto, Japan, for his electrophysiologic studies of laryngeal function

The International Committee for the Gould Award for 1959 will consist of Sir Victor Negus, 149 Harley St, London, W 1, Prof Cotoji Satta, No 111 Morikawa-cho, Bunkyo-ku, Tokyo, and Hans von Leden, M D, Medical Director, The William and Harriet Gould Foundation, 30 North Michigan Avenue, Chicago 2, Illinois

The amount of the Award has been increased to $300 00

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At home the mother was required to suction the nose every four hours For the next four months the infant would feed, breathe and sleep well for one week at a time As a result the patient was seen regularly at the office for thorough suctioning and dilatation of the choanal openings At eight months of age a revision was done by the intranasal route using a small biting forcep gouge and chisel The edges of the opening were removed by this means resulting in a good sized passage Following this the child has been breathing solely through the nose and suctioning was necessary only once daily in the morning Feeding proceeded normally and the infant slept through the night with quiet respirations

When last seen at the age of two years the child was completely normal in all habits feeding sleeping and breathing through the nose The breathing was quiet and the choanal openings were unchanged Examination of the ears pharynx sinuses and nasal cavity showed no abnormalities

A further revision may be done in the future, (the time will depend upon the progress of the child, whereby the remainder of the choanal bony plate will be removed) A transpalatine approach as advocated by Owens, etc, will probably be used The easier surgical approach employed in this case was thought advisable because of the age of the infant

603 Boyd Bldg

ANNOUNCEMENT

The Annual Spring Meeting of the Alumni Association of the New York Eye and Ear Infirmary will take place April 20-23, 1959, at the Infirmary

Symposia will be offered on Headache, Allergy and Immunology in Otolaryngology, Diagnosis and Treatment of Laryngeal Conditions, Hearing Rehabilitation, and Rhinoplasty In addition, there will be a closed circuit television demonstration of Head and Neck Surgery

Additional information may be obtained by writing to Dr John R Finley, Secretary, Alumni Association, 218 Second Avenue, New York 3, N Y

CONGENITAL BILATERAL COMPLETE BONY CHOANAL ATRESIA

JACK A. RUBIN, M.D.,

Winnipeg, Manitoba

The following case of choanal atresia as an emergency in the newborn, is reported.

CASE REPORT

K.V., a white female, newborn, was noted to have respiratory distress after a spontaneous delivery. Birth weight 6 lbs., 14 ozs. The pre-natal course had been uneventful. Direct laryngoscopy and chest examination revealed no abnormalities. An attempt to pass a nasal catheter via both sides of the nose was unsuccessful. A diagnosis of congenital bilateral choanal atresia was made.

The infant was placed in an incubator and given oxygen. Repeated nasal suctioning was necessary to remove the thick mucoid discharge, which kept reappearing at the anterior nares. It was noted that the child's color was good, and the respiratory difficulty disappeared when the patient cried; however, while feeding or lying quietly in its crib, definitely labored breathing, blue spells and indrawing of the intercostal and supraclavicular spaces would occur. The breathing was "noisy" and labored at all times, except when crying. X-rays of the skull did not show air in the nasal cavities, and for some reason contrast media was not instilled into the nasal cavities.

The infant was treated with oxygen and repeated nasal suctioning for the first 48 hours. Feeding was poor, and the infant began to show signs of dehydration and progressive asphyxia.

Otolaryngological consultation at age two days confirmed the diagnosis of bilateral complete bony choanal atresia. Neither catheter nor metal probe could be passed through the thick bony partition, via the anterior nares. Considering the state of the infant an emergency procedure was done as follows: After unsuccessfully attempting to push a trocar through the partitions a small gouge and mallet was used to punch an opening through both bony choanal walls. The results immediately following this were dramatic. The child fell asleep with no respiratory distress for the first time, and breathing through the nose was possible.

Following this, feeding and sleeping were normal; however, because of noisy nasal breathing, both choanal openings were enlarged slightly intranasally five days later. A polyethylene tube was placed in the nose through the choanal opening; however, the tubing had to be removed within 24 hours, as it interfered with nasal breathing. Because of a very shallow nasopharynx, the inner opening of the tube was partially obstructed.

The infant was discharged from the hospital at two weeks of age.

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controlled the convulsions but the patient immediately stopped breathing He was kept on controlled respirations for approximately one hour when spontaneous respirations returned During the prolonged period of respiratory paralysis the patient s pulse rate went up a little and on occasions became somewhat irregular His general condition however remained very good He was given 4 cc of Coramine intravenously after 30 minutes of apnea and this was repeated about 15 minutes later It appeared to have little effect One hour later he was able to answer questions but was still quite drowsy When seen later that day he was fully conscious and felt quite well He was discharged from the hospital next day and I hope to do a tonsillectomy with a general anesthetic soon

This man was a healthy farmer Neither he nor his family had any previous history of epilepsy He had a local anesthetic for a dental extraction two years ago with no reaction

SUMMARY

A case of convulsions after infiltrating the peri-tonsillar tissues with 25 cc of 1 00 per cent procaine with two drops of epinephrine, 1/1000, is reported Although the convulsions were controlled with Pentothal they returned when its effect began to wear off, approximately one-and-a-half hours later They were again controlled by Pentothal, and after a period of apnea of one hour's duration the patient made an uneventful recovery

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The Medical Center

PROCAINE CONVULSIONS

JOHN KEOHANE, M D ,

Stettler, Alta, Canada

Toxic reactions to local anesthetic drugs may be of a cardio-vascular system depressant, or a central nervous system stimulating type The latter may also be followed by the former more serious type of reaction

The entire subject of toxic reactions to local anesthetics, whether used by topical application or infiltration of tissues, has been very well reviewed in two recent publications[1,2] The following report is, however, of interest since it concerns a toxic reaction to procaine in a dose about one-quarter of the generally accepted maximum safe dose Procaine is also thought to be one of the safest local anesthetics

N D , a 26 year-old man, was admitted to the hospital on May 13, 1958 for a tonsillectomy under local anesthesia the following morning At 10 00 P M the evening before his operation, he was given Seconal, 1½ gr orally Next morning he had Seconal 1½ gr two hours preoperatively, followed by ¼ gr morphine and 1/200 gr atropine one hour preoperatively A few minutes after spraying his throat with a small amount of 2 per cent pontocaine solution, both peri tonsillar regions were infiltrated with a total of 25 cc of 1 00 per cent procaine with two drops of epinephrine, 1/1000 solution, added About two minutes after the last of the local anesthetic had been injected the patient became restless and excitable He was immediately put into a horizontal position and directions given to the operating room nurse to get a solution of Pentothal ready About 30 seconds later his face began to twitch and this was soon followed by a severe generalized convulsion

As soon as the Pentothal was available (approximately one minute after it was requested) the patient was given 10 cc of a 2 5 per cent solution intravenously (250 mg) Meanwhile oxygen was given from an anesthetic machine The convulsions were quickly controlled Pulse respiration blood pressure and color were soon within normal limits An intravenous drip of 5 per cent glucose in water was started, to have ready access to a vein After observing the patient for a little longer the oxygen was discontinued and he was transferred back to bed A solution of Pentothal in a syringe and the anesthetic machine was brought to the patient's bedside in case of further trouble

A little over an hour and a half later I was urgently called to see the patient. It took me approximately two minutes to get to his bedside He was having a severe convulsion, which had commenced two minutes previously (when he began to recover from the effects of the Pentothal) and showed no sign of abating A further 8 cc of Pentothal (2 5 per cent)

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concept of alteration of nasal pH to the alkaline side in nasal infection may be a defense mechanism and, therefore, the effect of the early stage of infection rather than the cause

DISCUSSION

Dr Aubrey G Rawlins brought out some of the relationships between the corticosteroids and the ground substance whose density is regulated by the pituitary adrenal axis The efficiency of this axis may be one determining factor in the invasiveness of certain organisms Dr Hopp has furnished good evidence that hyaluronidase-producing bacteria are often more invasive than non producers and this would be an important factor in many nose and throat infections The authors have shown how the spreading factor loosens the basement membrane under the epithelium resulting in easier invasion by organisms

Not much is known as to whether or not there is any spreading factor in the normal nose and throat mucosa however it must be assumed that its precursor is there since the existence of hyaluronidase and mucolytic enzymes in the connective cells has to be postulated if equilibrium of the ground substance is to be explained

Dr Hopp mentioned the anti spreading factor of which there are two types the antibody which is specific and the heparin like substance which is non specific and is high in the blood stream in many diseases of a serious nature

The authors have well emphasized the dual features of infection namely the virulence and characteristics of the infecting organism and the quality of the ground substance of the host.

Dr George Kelemen showed several electron microscopic slides of tonsil tissue which at high magnification (30 000) depict the elements in the collagenous material the fibrillar structures and the relationship of the epithelial cells to each other Since these are joined together by intercellular bridges it can be seen how the lymphocytes have to push their way through by breaking down these bridges

Electron microscopy can contribute much of our knowledge of tissue reaction to infection by bringing out the finer anatomic details of the various elements under varying conditions

Dr Hopp in closing stated in response to Dr Rawlins' query that in 1931 filtrates were taken from the normal nose as well as from individuals having a cold and it was demonstrated that there were spreading factors in the normal noses and interestingly enough there was an increase in the spreading factor in the patients with colds at that time

Dr Kelemen's slides are most interesting and suggest the possibility of applying some of these histochemical staining techniques to the study of tonsil material

ABSTRACT OF THE PROCEEDINGS
OF THE
SEVENTY-NINTH ANNUAL MEETING
OF THE
AMERICAN LARYNGOLOGICAL ASSOCIATION

San Francisco, Calif, May 19-20, 1958

HARRY P SCHENCK, M D,
President

SAMUEL SALINGER, M D,
Abstract Editor

GROUND SUBSTANCE IN THE NOSE IN HEALTH AND INFECTION

EUGENE S HOPP, M D,
and
HELEN F BURN, M S (By Invitation)

These authors present the evidence thus far accumulated by themselves and others relating to the permeability of the ground substance in nasal tissues under varying conditions and the factors which permit certain bacteria to penetrate and spread Spreading factors, notably hyaluronidase, seem to be more abundant in staphylococci than in most streptococci, which enhances their invasive potentialities The hyaluronidase possesses the ability to depolymerize the hyaluronic acid in connective tissue, thus favoring the spread of infection These findings resulted from comparative multiple stain techniques of serially sectioned biopsies of turbinates from normal individuals and from patients with infection The authors conclude that since hyaluronidase is most active in the range of normal, slightly acidic nasal pH, the accepted concept of alteration of nasal pH to the alkaline side in nasal infection may be a defense mechanism and, therefore, the effect of the early stage of infection rather than the cause

DISCUSSION

Dr Aubrey G Rawlins brought out some of the relationships between the corticosteroids and the ground substance whose density is regulated by the pituitary adrenal axis The efficiency of this axis may be one determining factor in the invasiveness of certain organisms Dr Hopp has furnished good evidence that hyaluronidase-producing bacteria are often more invasive than non producers and this would be an important factor in many nose and throat infections The authors have shown how the spreading factor loosens the basement membrane under the epithelium, resulting in easier invasion by organisms

Not much is known as to whether or not there is any spreading factor in the normal nose and throat mucosa however it must be assumed that its precursor is there since the existence of hyaluronidase and mucolytic enzymes in the connective cells has to be postulated if equilibrium of the ground substance is to be explained

Dr Hopp mentioned the anti spreading factor of which there are two types the antibody which is specific and the heparin like substance which is non specific and is high in the blood stream in many diseases of a serious nature

The authors have well emphasized the dual features of infection namely the virulence and characteristics of the infecting organism and the quality of the ground substance of the host.

Dr George Kelemen showed several electron microscopic slides of tonsil tissue which at high magnification (30 000) depict the elements in the collagenous material the fibrillar structures and the relationship of the epithelial cells to each other Since these are joined together by intercellular bridges it can be seen how the lymphocytes have to push their way through by breaking down these bridges

Electron microscopy can contribute much of our knowledge of tissue reaction to infection by bringing out the finer anatomic details of the various elements under varying conditions

Dr Hopp in closing stated in response to Dr Rawlins query that in 1931 filtrates were taken from the normal nose as well as from individuals having a cold and it was demonstrated that there were spreading factors in the normal noses and interestingly enough there was an increase in the spreading factor in the patients with colds at that time

Dr Kelemen's slides are most interesting and suggest the possibility of applying some of these histochemical staining techniques to the study of tonsil material

VOCAL REST IN LARYNGEAL DISEASE

MERVIN C MYERSON, M D

Vocal rest must be intelligently applied and varies with the pathology in each case It is of greatest value in acute cases where inflammation and edema predominate, and less useful in chronic cases characterized by fibrosis and irreversible changes, therefore, it is of no value in the treatment of vocal nodules or in the chronic stages of contact ulcer It is useful in the preoperative days before removal of tumors and should not be prolonged postoperatively Delay in permitting the patient to speak in some cases may lead to psychologic trauma Within a very few days after surgery the voice may be used for moderate conversation, avoiding undue strain

DISCUSSION

Dr Louis H Clerf agreed in the main with Dr Myerson's conception of the role of vocal rest in laryngeal therapy Contact ulcers will not disappear under this plan except when they are of very recent origin In both vocal nodules and contact ulcer, speech therapy may be of some value, in addition to surgery when indicated Pre- and postoperative vocal rest, particularly the latter, should not be prolonged Voice use after operation should be permitted, since it prevents the piling up of exudate and granulations and tends to a better anatomical and functional result

Dr C L Jackson favored moderate rest of the voice in the conditions mentioned by Dr Myerson, but cautions the patient not to attempt talking against noises such as in traffic or busy offices In the treatment of contact ulcer he believes there is a time and place for cautious use of the voice but also it is important that the patient have the benefit of guidance under a speech therapist Like Dr Clerf, Dr Jackson encourages patients who have undergone partial laryngectomy to begin using the voice as soon as it can be done without discomfort

Dr Hans Von Leden said that electronic synchrostrobic examinations with high speed photography can furnish much valuable information about the action of the vocal cords under varying conditions On the basis of such observations he felt impelled to challenge Dr Myerson's statement that certain lesions disappear in 24 hours To the naked eye they may appear to shrink but "one must consider the effect of the Bernoulli phenomenon on the lesions of the vocal cords before one draws any clinical conclusions"

Dr Paul J Moses pointed out that voice rest is often advised in the expectation of curing a disorder, but frequently fails because of an underlying psychological problem which is the chief cause Voice rest will not cure a vocal disorder that is due to emotional causes It is therefore important in many cases that a psychiatric evaluation be obtained before any type of therapy is proposed

Dr Myerson closed the discussion with the following comments Bi opsies are usually not necessary in contact ulcers since it is known that carcinoma rarely occurs on the medial aspect of the arytenoid cartilage As for raising the voice in the presence of noise mentioned by Dr Jackson, this can be avoided by using ear plugs as advised by Mr Cantor Since the electronic synchrostroboscope is not available universally the laryngologist must depend on his clinical observations, and he personally can attest to a number of edematous lesions which have disappeared within 24 hours and with return of perfect function

Dr Moses remarks are well taken and bring up the point as to what constitutes a qualified voice therapist Many who claim this distinction have been found to be woefully deficient Psychotherapy may well be the answer in many cases but there are some patients of the exhibitionist type such as a night club singer upon whom he had operated to remove some vocal nodules who refused to undergo proper voice therapy and with the recurrence of the nodules blamed the surgeon

PANEL DISCUSSION

REHABILITATION OF THE POST-LARYNGECTOMIZED PATIENT

JOHN J CONLEY M D, *Moderator*

Rehabilitation of the Post-Laryngectomized Patient—
Charles M Norris, M D

Vocal Therapist Place and Contribution to the Rehabilitation Program .... Paul J Moses, M D

Rehabilitation of the Post-Laryngectomized Patient—
F Johnson Putney, M D

Psychological Factors Determining the Success or Failure of the Rehabilitation Program of Laryngectomized Patients—
Bernard Stoll, M D

Discussion of Some Technical Aspects of Speech Aids for Post-Laryngectomized Patients .... Harold L Barney, M D

A New Surgical Technique for the Vocal Rehabilitation of the Laryngectomized Patient .... John J Conley, M D,
Felix DeAmesti, M D,* and
Max K Pierce, M D *

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*By invitation.

John J Conley, M D, Moderator, introduced the members of the panel who were to discuss various aspects of the problems of rehabilitating the laryngectomized patient These were to include surgical aspects, electrical equipment for voice production and speech therapy Some of these aspects have to some degree been overlooked in the past, and although some progress has been achieved, further study may prove fruitful in resolving the problems which confront these patients

Dr Charles M Norris lists the deformities and disabilities likely to be encountered following extensive laryngeal and accompanying pharyngeal and neck resection These are considered in two groups first, are those resulting inevitably from the surgery itself, such as permanent tracheostomy and loss of sensation due to section of branches of the cervical plexus and of function of the trapezius from section of the spinal accessory

The second group comprises deformities which may or may not be avoided, depending upon the technique These include stenosis of the stoma, stenosis of the hypopharynx, and paralysis of the mandibular, lingual or hypoglossal nerve, also the effects of sectioning the jugular vein

Dr Conley commented on the clear orientation of the operated area, the relative sizes of the wound, the demands on the local tissues and the resultant deformities This demonstration should be valuable in assessing the surgical damage inherent in various procedures

Dr Paul J Moses discussed the emotional status of the patient prior to a laryngectomy and its influence on the postoperative rehabilitation Restoring the ability to produce audible speech fails to compensate for the inability to transmit the nuances of feeling which no form of esophageal speech can duplicate It is, therefore, important that the speech therapist be properly trained in the field of psychology and psychiatry in order to obtain the full background of the patient's personality and to be able to adjust him properly to the altered status of voice production Placing him under the guidance of a laryngectomized patient who has mastered the technique of esophageal speech may fail unless the latter is qualified to understand and cope with a neurotic or psychiatric patient It is also important that the surgeon keep in close contact with the patient during the postoperative period while under tuition of the speech therapist, since it is he who is responsible for having taken away the speech, and who must display the keenest interest in seeing that it is restored

Dr Conley, hearing this paper for the first time, found it stimulating, provocative and humanistic The symbolism he attached to the "Adam's apple" as an attribute of virilism in the male may well explain the differing attitudes of the male and female when anticipating removal of the larynx The high artistic and esthetic quality of Dr Moses' presentation should be fully appreciated by all who are interested in the subject

Dr F Johnson Putney, reviewing the postoperative records of 440 patients subjected to a laryngectomy at the Jefferson Hospital, found that 38 per cent failed to develop a useful voice The percentage of failures was higher in the female patients than the male, due to psychologic factors The various techniques employed seemed to have but little influence on the ability to develop a voice, even when extensive removal of pharyngeal tissues, including the cricopharyngeus, was necessary, however, it was found that disturbance in the range of activity of the tongue and muscles of the floor of the mouth interfered with the ability to produce a voice as well as with the act of swallowing

It would appear, therefore, from the analysis of this group of patients, that failure to develop a voice could not be attributed to extent of the surgery or the amount of tissue removed, with the exception of the item just mentioned

Dr Conley called attention to figures presented by Dr Putney, where only 5 7 per cent of 440 patients elected to use an artificial larynx Comparing this with 38 per cent of the cases that failed to become rehabilitated vocally, this is pretty much in line with the figures obtained at the National School for Speech Disorders in New York It is interesting to note that no matter how much neck tissue is removed, rehabilitation is possible as long as you reconstitute the pharyn-

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Dr Bernard Stoll, in attempting to evaluate the patient's attitude toward rehabilitation, enumerated the fears that beset most patients prior and subsequent to operation The degree of anxiety varies with the temperament of the patient, his vocation, position in society and interpersonal relationship Preoperative counselling by the physician will remove many of these fears and the presence of an intelligent, psychologically astute person, who has undergone a laryngectomy and has acquired a good esophageal speech is very helpful Instruction within a group of laryngectomy patients lends psychologic support through the competitive element

Necessity and willingness to learn are most essential, and as a rule, it has been found that the extrovert type of individual adapts himself to the new regimen better than the introvert It is important during the periods of instruction to avoid the use of the word "belch" because of its disagreeable connotations

Psychologic conditioning whereby the patient acquires confidence in the ready acceptance by the public of his newly acquired speech is most helpful in instilling the necessary confidence

Dr Conley stated that Dr Stoll's paper illustrates very well the necessity for adaptation on the part of the patient in order to master the technique successfully One can regard the patient as standing on a ladder, you either push him up into an area of greater success, if he has the adaptive capacity and necessary motivating principles, plus the support of proper schooling, or he will slip backward into failure to achieve adequate rehabilitation If the speaking phenomenon can be made technically easier the stratum is lowered thereby putting it within reach of the patient's adaptive capacity

Dr Conley apologized for the absence of the film which was scheduled to be shown, due to an error on the part of the Phillips Company, who sent a film of the palate instead of the esophagus

Mr Harold L Barney, of the Bell Telephone Laboratories, analyzed the problem of constructing an artificial larynx that will meet certain mechanical acoustic and commercial requirements Improvements have been achieved with the introduction of transistors and miniature batteries, however, the ideal has not yet been attained insofar as being able to produce speech patterns which will more closely simulate the normal In order to obtain the full advantage of tongue, lip and palate movements, as well as the resonating chambers above, it would be necessary to introduce an air column as low down in the pharynx as possible If this could be achieved *through an artificial opening in the neck, it would be ideal*, but there are certain hygienic and cosmetic considerations, which are objectionable

The author showed graphs which demonstrated the sound spectograms for certain vowels and consonants with the tube at different locations as compared with the normal

It is anticipated that the Western Electric Model 2 device, improved with proper acoustic and electronic circuit design, should provide sufficient drive when applied to the outside of the throat to produce adequate intelligibility which will result in more natural sounding speech

Dr Conley and associates describe a new technical procedure whereby air can be conducted from the trachea to the esophagus for the production of controlled sound It is accomplished by the construction of a mucosal-lined tube derived from the esophageal mucosa supported by one of the neck muscles and so directed as to be closed during the passage of food The operation was performed on 11 patients, eight as primary procedures following the laryngectomy, and three as secondary procedures Of the eight primary, three were technical failures (two of stenosis and one through fistula formation) The stenosis may have been due to removal of the catheter stent too soon The fistula formation was in a patient who had had irradiation prior to laryngectomy

In the successful cases the patients were able to speak with the first effort, and the quality of the voice was that of pharyngeal or esophageal speech but with better air control and supply and greater ease

DISCUSSION

Dr Julius McCall called attention to his paper on "Preliminary Voice Training for Laryngectomy" of 18 years ago, which set in motion the development of what was termed "The Lost Chord Club" It is his contention that training for the esophageal voice should begin before and not after surgery, also he disagreed with Drs Moses and Stoll, who deny that the expulsion of air is not a burp or a belch He could recall only two patients who were able to belch after laryngectomy who failed to develop a good esophageal speech He agreed with Dr Putney that the amount of tissue removed had little to do with the subsequent development of the speech

Dr Joseph H Ogura had little to add, expressing his agreement with everything that had been said

Dr McNaught echoed the same sentiments

Dr Louis H Clerf felt that while the opinions expressed were in many respects admirable, he could not agree with everything, since some of them were diametrically opposed It is generally agreed that the problem is one from which the surgeon cannot divorce himself It is he who must take the initiative in getting the patient started since it is he in whom the patient has the greatest confidence He agreed with Dr McCall to the extent that whether you call it belching or burping you have to get air into the lower pharynx Where the dividing line is located is difficult to say He does not have the patient deliberately swallow but encourages him to relax during inspiration so that air may accumulate in the lower passages He himself has been able to relax his cricopharyngeus sufficiently to fill the stomach with air

Dr Paul H Holinger agreed with Dr Putney that the type of operation has little to do with the subsequent development of a speech pattern He believed that the most important factors are the motivation by the patient and intelligent co operation of therapist and surgeon Often it is a question of persisting too long in efforts to produce esophageal speech in some cases to the point of frustration when such individuals can more readily be made to accept an artificial larynx With improved models of prothesis this medium may become more acceptable As to preoperative training he disagreed with Dr McCall because it is so often an individual problem In some cases it only adds to the burden on the patient, who has many other things to attend to before undergoing surgery Rehabilitation and inspiration to learn can begin before the patient leaves the hospital through association with others who have acquired speech and instruction by the therapist

Dr Conley agreed with Dr Holinger that one of the most important psychological points is the compulsion of the patient to speak It may be a good idea to give the patient a speaking apparatus at the outset as a means of encouraging adaptation

Dr Walter H Hoover could not entirely agree that the type of operative procedure played no role in subsequent speech development. Certainly a flexible pharynx will adapt itself to voice production better than one which is hampered by deep neck scars

Dr Conley closed the discussion by stating that the purpose of the panel was not so much for medification as for a stimulus to all laryngologists and allied specialists to apply themselves toward the development of new techniques which may further the advancement of knowledge in this most important field

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THE CHANGING YEARS THEIR IMPACT UPON THE MANAGEMENT OF PARANASAL SINUS DISEASE

FREDERICK T HILL, M D

Dr Hill reviewed the changes that have taken place during the past 40 years in the management of sinus disease, showing how increasing knowledge of the physiology of the nose and sinuses and a better understanding of constitutional and environmental factors has led to a saner and safer attitude He mentioned the excellent research and contributions of many members of this association which were responsible for the advances we have witnessed He discussed the impact of allergy, endocrines and other constitutional factors as they were developed within and without our specialty, whose influence on the course and development of sinus conditions was studied by our colleagues, resulting in a more intelligent understanding of the pathogenic processes Surgical procedures have as a result tended more and more to conservatism, as demonstrated in his analysis of the treatment of frontal, ethmoid and antrum disease Comparing the widespread and often indiscriminate surgery of the sinuses formerly practiced on fallacious indications, with the modern conception of the sinuses as part of a total organism, it is easy to see why we are doing less surgery and obtaining better results under a comprehensive regimen which takes into account all of the contributing factors

DISCUSSION

Dr Samuel Salinger confessed to an emotional reaction to Dr Hill's presentation which was primarily a response to the realization that he was older than he had thought and secondarily to an amazing change in perspective

Recalling for instance a meeting some years ago at which a colleague reported having done 300 intranasal frontal operations with a rasp and with only one fatality, he is now shocked to think that at the time he was only impressed by the great skill of the surgeon without having given any thought to the question of why these operations were done

To comment on the numerous items so ably assembled by Dr Hill would be superfluous, but one or two personal observations are submitted One should always be suspicious of any unilateral clouding of a sinus that is more than transitory, and should never be guilty of overlooking the possibility of a malignancy, which is so difficult to diagnose in the early stage It is for this reason that he is a firm believer in the value of laminagraphs and X rays with contrast media in every case that fails to yield promptly to conservative treatment

Another conclusion to which he has been forced is that the only way to insure against recurrence after frontal sinus surgery is to obliterate the cavity He was impressed with the work of Bergara, who uses abdominal fat to fill the sinus and has presented evidence of subsequent development of fibro-osteoid tissue completely filling the space In two recent cases Salinger has used Gelfoam instead and in following the cases with X rays for several months, has been able to observe a gradual obliteration of all bony landmarks This may or may not mean a permanent filling, but only time will tell

Dr Francis L Weille believed that the role of allergy has been overemphasized Many people believe that the allergist can cure recurring polyposis with anti allergic therapy He recalled a report by Dr Schenck and Dr Kern on a series of 700 cases a third of which had polypi in which only four were cured by anti allergic therapy He would like an expression from Dr Hill on this point

Dr Hill closed the discussion by stating first, that he agreed with Dr Weille as to over-emphasis on the allergic factor although he had seen a number of cases in which this cannot be denied Yet he doubts that polypi will disappear under allergic therapy except under the most unusual circumstances

The subject of malignancies as well as complications was not presented, although both are included in the full paper to be published As for Dr Salinger's opening remark regarding the passing of time, he could say only that one thing worse than growing old is not having a chance to do so!

SURGERY TO THE NASAL LOBULE

HENRY L WILLIAMS, M D

Dr Williams described in detail the anatomy of the nasal structure with special emphasis on the relationship of the septum to the lateral and alar cartilages Variations in the nasal apertures are responsible for varying effects on the degree of resistance to the inspired air which produce symptoms of hyper- or hypoventilation He pointed out that in most patients it is impossible to demonstrate the physiologic effects of these variations, and that from a practical point of view operations are indicated for the relief of subjective symptoms He described the symptoms caused by nostrils that are too narrow deformities of the lobule, deviations of the lower portion of the septal cartilage, variations in the size and placement of the lateral cartilages and nasolabial angles

The procedures for correcting these manifold conditions involve a combination of techniques which may embrace the septum, upper lateral cartilages and the lobule The septum is dealt with through a modified resection with replacement of excised cartilage, and the lateral and lobular cartilage resected in part or cross-hatched as indicated These techniques were given along with appropriate illustrations Good functional results can be obtained only through careful study of the individual case, applying only those remedial measures which are strictly indicated

DISCUSSION

Dr G Edward Tremble described the anatomic differences between the nares of the Caucasian as compared with the Negro and Filipino which account for differences in the direction of the air flow within the nasal passages These are to be taken into account when surgery is to be undertaken which involves changes in the contour of the nares and vestibule so that the normal pattern of air flow is not to be altered The shape of the nares must conform to the normal Caucasian, when operating on a white individual and the vestibule must retain the normal valve of Mink so that the air current is properly directed

Frequently after a properly performed submucous resection nasal blockage will be complained of which can easily be corrected by a simple procedure on the lobule

Dr Samuel Salinger felt that, since Dr Williams had introduced the subject of the septum in his consideration of deformities about the lobule he would like to comment on that aspect of the problem He has long been an advocate of a conservative type of operation in which the deformity is corrected with removal of a minimum of cartilage and bone Others have had the same idea and a variety of procedures have been described by Stevenson Dingman Becker and Maliniak In all these techniques the Metzenbaum procedure has been more or less modified the objective being the straightening of bends curves and cartilage The point is that no single technique is applicable to all cases and that success depends on the ingenuity and technical skill of the individual operator

Dr Irving Goldman called attention to the varying shapes of the nares to be found in different races and the question as to how much influence they exert on the respiratory function Changing the shape of the lobule may be applicable in one type and disastrous in another In the combined septum rhinoplasty with surgery of the lobule he is convinced that the causative factor is most generally to be found in the septum and he agrees with Dr Salinger that conservative procedures will yield the best results

Dr Juergen Tonndorf disagreed with Dr Tremble in the statement that there is a substantial difference between the currents of inspired and expired air Experiment of older authors did make this claim, but it was found that the difference was due to the use of too heavy material It was disproven 20 years ago in Dr Proetz's experiments He also may have misunderstood Dr Tremble as saying the current slows down as it goes through the vestibule On the contrary, when a current of air passes through a narrow opening, its velocity must increase The third point refers to the eddy motion of the air which through the nose is more laminary and unstable If you calculate the Reynolds' number which indicates whether the motion will be laminary or eddying it develops that the Reynolds number for the nose is about 1,000 in eddying It starts at 1,100 or 1,200 This means that you are just short of eddying, and if surgery does anything to speed up the flow of air you will produce an eddying current

Dr Wilson stated that we are led to believe that the Caucasian nose is narrower than the Negroid type because of living in colder and drier climates Could Dr Williams offer any explanation of the shape of the Eskimo's nose?

Dr Williams closed the discussion by first answering Dr Wilson's query to the effect that not being privy to the designs of the Lord, he was unable to offer any explanation, nor did he believe the anthropologists could

As to the remarks of Drs Salinger and Goldman, the technique he has described here offers great flexibility and permits surgery on the lobule at the same time He agrees that there is no set technique

The question as to whether the various types of noses have to do with varieties of obstruction is beyond the point Patients come to the surgeon because of obstruction, and in many instances the submucous resection is inadequate, and better results can be obtained by additional surgery on the lobule

What the mechanism of obstruction from lobular deformities is, he would leave to mathematicians such as Dr Tonndorf, but the fact remains that patients are relieved of their complaint when the deformities are properly corrected

CARCINOMA IN SITU OF THE LARYNX A TEN-YEAR STUDY OF ITS HISTOPATHOLOGICAL CLASSIFICATION, PROGNOSIS AND TREATMENT

ALDEN H MILLER, M D,

and

H RUSSELL FISHER, M D

Drs Miller and Fisher, analyzing a series of 48 patients with carcinoma *in situ* of the larynx, observed during a ten-year period, certain data pertaining to classification, local characterists, invasive potential and results of therapy Of the three histologic types encountered, basal cell, squamous cell and Bowmanoid, the most common was the squamous cell, which appeared to be associated with leukoplakia Ten patients developed invasive carcinoma, most of them originating from the squamous type Treatment by stripping, laryngofissure or X-rays was individualized on the basis of extent of the lesion, original diagnosis and development of recurrence Laryngofissure was successful for the small lesions More extensive lesions, especially the bilateral, received X-ray therapy, which obviated the need for laryngectomy in 17 of 23 patients

There was only one death following laryngectomy with subsequent invasion of the lymphatics and a radical neck dissection

DISCUSSION

Dr Francis E LeJeune brought out the point that the clinical picture of carcinoma *in situ* was not characteristic and that its differentiation from invasive carcinoma could be determined only by the pathologist. The question as to whether the lesion has penetrated the basal membrane can be resolved only through serial sections and since it is impractical to examine all the sections in a given specimen it is possible that some invasive cases may escape detection and thus account for recurrences

He has found carcinoma *in situ* ideal for removal by suspension laryngoscopy with wide excision followed by electric coagulation of the base Dr LeJeune inquired of Dr Fisher as to why he found it necessary to use the words without invasion in referring to these growths since penetration of this barrier changes the picture and one is now dealing with an invasive carcinoma and not a carcinoma *in situ* He would also like Dr Miller to explain why he was impelled to do laryngofissure in some of these cases

As to statistics he has not had an opportunity to review his own but is under the impression that he had seen very few recurrences

Dr Eugene S Hopp suggested a possible explanation for invasion which might reconcile the points of view of Drs LeJeune and Fisher namely that invasion and even metastasis depends on the integrity of the ground substance Some excellent work has been done showing that metastases develop where depolymerization of ground substance has taken place It would be interesting and profitable to do histochemical stains on these carcinomas with the idea of ascertaining whether those which subsequently developed extension or invasion showed this depolymerization in the sections and whether those which did not develop showed intact ground substance

Dr Julius McCall would view carcinoma *in situ* as an unpredictable lesion As stated by Dr LeJeune much depends on the area from which a biopsy is taken since a distance of a few millimeters may produce an entirely different picture This was illustrated in pictures shown by Dr

McCall of a case where one section showed intact basement membrane, whereas another showed a break through

Dr Miller closed the clinical side of the discussion by stating that he had attempted to make the distinction between the strictly intraepithelial growths and those showing invasion, the latter being excluded from the series, if *recognized*

Regarding the potentially malignant character of these lesions Dr Miller agreed with Dr LeJeune that *every case is potentially invasive* although in many cases the invasive character is not manifested until years later Initially a clinical diagnosis cannot be made from the appearance of the lesion, many of them being leukoplakia cases on the surface

Dr Fisher explained his terminology "without invasive carcinoma" to emphasize that all parts of the tissue had been examined He may perhaps have been too redundant for this audience but has so often been asked "was there not invasion in some other part" that as a result it has been his habit to add the words "without invasive features"

The point brought up by Dr Hopp is an important one and it must be conceded that the character of the ground substance has much to do with the chance of invasion He has made *studies in a few cases but not* systematically Alterations in the ground substance have been observed in simple keratosis, chronic laryngitis as well as carcinoma *in situ* without however revealing any specific change characteristic of carcinoma *in situ* Dr McCall's case brings to mind the studies on carcinoma *in situ of the cervix in which a potential to invasion has been more or less* fixed By comparison the cases involving the larynx occupy a place midway between the peak age of cervix lesions and keratosis being estimated at about eight years Dr McCall's slides demonstrate the difficulty that arises when only one section is examined One slide appeared to be simple metaplasia another showed carcinoma *in situ* at one spot, and another showed it with invasion

BRONCHOSCOPIC FINDINGS IN TUBERCULOUS CHILDREN (A FIFTEEN YEAR STUDY) *

Dr Whaley described the results of their bronchoscopic examinations of 144 children with bronchial tuberculosis *Many of these had bronchograms as well, and a total of 273* examinations was made They give the details of the procedure, which is carried out under general anesthesia in a properly ventilated room with shock and explosion-proof apparatus

Primary bronchial tuberculosis was found in a limited number of cases, the result of direct infection of the mucosa, which revealed redness and swelling over a limited area Most commonly the upper lobe bronchi and the lingula were affected

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*Due to the untimely death of Dr Wishart this paper was presented by Dr Whaley

Secondary tuberculous bronchitis was found more frequently and often called for emergency treatment Compression of a bronchus due to pressure of enlarged glands was a common finding, and frequently there was an accumulation of caseous material and granulations, due to rupture of a caseous gland into the lumen These called for bronchoscopic removal Other findings were bronchiectatic lesions of the "flagellate" type

Following unsuccessful trials with streptomycin, para-amino-salicylic acid (PAS) and isotonic acid hydrozide (INH) proved more successful Repeated bronchoscopic aspiration with removal of granulations was helpful in many cases In a few it was necessary to resort to lobectomy and occasionally to pneumonectomy

Numerous pictures showing bronchograms illuminated the presentation

DISCUSSION

Dr Mervin C Myerson found that the age group below two years is the worst from the standpoint of prognosis In the group between the age of 4 and 14 about 15 to 20 per cent present the type of lesion seen in adults In the infant and young child the glands cause the most trouble often to the point of obstructing the bronchi These glands may develop in two directions one erosion into a bronchus the other by lymphatic extension to the bronchial mucosa This may be either a submucous infiltration or an open ulceration Dr Myerson showed slides depicting lesions in the parenchyma and showing the manner of extension to the bronchi Generally speaking one may safely attempt to remove a granuloma but if the lesion is caseous surgical trauma might precipitate a miliary spread to other parts of the body also he would not recommend dilating a bronchial stenosis because of a hematogenous spread

Dr J P Atkins has found that it is safe to remove endobronchial caseation debris without danger of dissemination probably due to the effectiveness of the antibiotics and the improved ventilation is certainly beneficial

Dr Whaley in closing agreed with Dr Myerson that many cases do not respond to endobronchial therapy and have to submit to surgery As for the caseous lesions he agreed that cautious removal of the debris is desirable while on the other hand as Dr Myerson pointed out dilatation is risky

THE CLINICAL SIGNIFICANCE OF THE ANATOMICAL ARRANGEMENT OF THE PARANASAL SINUSES

FRED W DIXON, M D

A study of 200 wet specimens by Dr Dixon yielded a number of observations which have proven of value in surgery of these areas These include the accessibility of the middle meatus for irrigation of the antrum, the variations in size and disposition of the ethmoid cells, the variations in size and relative positions of the two frontal sinuses and the extreme variability of the sphenoid sinuses Dr Dixon pointed out the value of closely observing the fovea ethmoidalis, which is an excellent landmark when performing surgery on the ethmoids via the intranasal approach Preserving as much as possible of its mucosa, plus that which covers the superior and supreme turbinals, and as much as possible of the middle turbinate will prove valuable in avoiding complications

Recurrence of polypi can be expected if the surgery is incomplete and in allergic individuals A resume of 200 intranasal ethmoidectomies showed 25 per cent with recurrences, mostly in allergic cases and in individuals who rejected complete removal

DISCUSSION

Dr Walter P Work stressed the points brought out by Dr Dixon relating to the variations of the frontal sinuses In narrow frontal sinuses it is extremely difficult to preserve a functional frontal duct The chances are better in cases where the anterior dimension of the sinus is greater Surgical treatment of the frontal sinuses must of necessity include associated surgery of at least a portion of the ethmoid labyrinth and here a knowledge of the disposition of the cells is of great value

Dr Work has found that serious complications were most frequently encountered in the allergic cases and inquired of Dr Dixon whether this had been his experience also

Dr Barry J Anson, as an anatomist expressed his appreciation in having been able to hear two papers dealing with the morphology of the sinuses At the onset of the antibiotic era he had been led to believe that the mention of sinusitis would be an anachronistic act Now that it appears that sinusitis still exists despite antibiotics he fears curricular encroachment by clinical courses on the time formerly available for preclinical courses In his department he has already lost 30 per cent of previously allotted time Since it is apparent that hours must be recaptured for teaching anatomy the pressure and influence must come from the clinicians Meanwhile postgraduate lectures of the type presented here are refreshing and helpful additions to make up for deficiencies in the undergraduate instruction

Dr W Likely Simpson described his approach to the frontal sinus through the floor with complete removal of all mucosa and all septa between the frontal and the ethmoids Visualization of all parts of the large sinus is accomplished with the use of small mirrors No irrigation is practical and only a small gauze is left under the middle turbinate which is removed on the third day No further drainage is employed since there is no nasofrontal duct left, the fronto-ethmoid cavity being all in one

Dr Francis W Davison complimented Dr Dixon on his paper and called attention to a previous presentation of his which was given at the meeting of the American Laryngological Association which he considers a classic He inquired as to when and where this was to be published

Dr Kinsey M Simonton called attention to Dr Dixon s reference to removal of the middle turbinate which has been invaded by a cell He has found it practicable to remove only one wall thus leaving the other for physiologic functioning

Dr Dixon closed the discussion by first replying to Dr Simonton It is his practice to leave as much of the turbinal structure as possible on the side facing the septum This has proven helpful in preserving the olfactory sense

The article mentioned by Dr Davison will appear in the *Annals* He agrees that the operation for removal of polypi should be done in the hospital where a more thorough job can be accomplished and also agrees with Dr Simpson that thorough removal of all the tissue will yield the best results

Dr Anson s point is well taken We need more teaching of anatomy and pathology at the undergraduate level

About swimming like all rhinologists he feels that it should be interdicted for all patients having chronic sinus trouble

As to indications for the operation it should be required in all cases where ventilation and drainage has failed and where irreversible changes have taken place

ORBITAL APEX SYNDROME

AUSTIN A SMITH, M D

Dr Smith described the orbital apex syndrome as the clinical manifestation of a lesion which affects the nerves and vessels that pass through the optic foramen and sphenoid fissure The chief symptoms are severe temporoparietal pain, impairment or loss of vision, ptosis and ophthalmoplegia It may be due to infection, neoplasm or trauma, and can originate either in the retro-orbital region or in the posterior sinuses

Five cases are cited one being due to a severe upper respiratory infection, one to a posterior sinus infection, a third to a carcinoma originating in the ethmosphenoid area The fourth was a complicated case which, after careful study and radical surgery, proved to be an extensive involvement of all the sinuses in a gangrenous destructive process with necrosis apparently due to endarteritis and thrombophlebitis The last case was due to trauma resulting from a fall from a ladder

The clinical history of these cases affords an interesting study in diagnosis and therapy

DISCUSSION

Dr Oliver E Van Alyea pointed out some of the anatomic features of the orbital apex, explaining the symptomatology

The complete syndrome as described by Dr Smith is, fortunately, quite rare, but an uncomplete syndrome may be more common Two cases are cited one due to an aneurysm of the internal carotid artery, the other, to a retrobulbar cyst This latter patient, a girl of 13, after drainage of the cyst still persisted in having severe headaches and a mild ptosis Surgery on the affected ethmoid was advised, but was rejected by the parents on religious grounds Dr Van Alyea asked Dr Smith how he would proceed in such a case

Dr Smith replied to Dr Van Alyea's question by calling attention to the necessity of having the cooperation of the neurologist, ophthalmologist, neurosurgeon and X ray man Too often, however, the case goes from internist to ophthalmologist and neurologist and X ray man without consultation with the rhinologist, because the possibility of a sinus involvement is overlooked This may be due to the fact that antibiotics have often been considered as having eliminated sinus disease This is indeed a grievous error In the particular case mentioned by Dr Van Alyea, every effort should be made to at least explore the ethmoids cautiously

PHYSIOLOGY OF THE LARYNX UNDER DAILY STRESS

PAUL G MOORE, M D ,[*]
and
HANS VON LEDEN, M D [*]

Drs Moore and Von Leden demonstrated the action of the vocal cords in a slow motion film which reveals their responses under daily stress Numerous subjects were checked and rechecked to insure the accuracy of their interpretations Two new ideas ensued following a study of the film which seemed to alter previous concepts of the physiology of the larynx

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[*] By invitation.

1 The old concept that the cords open faster than they close is not true Opening and closing phases are related to the intensity of the voice

2 The larynx is capable of biphasic movements, which to date had been considered impossible

It is hoped that these studies will lead to a better understanding of the frequently observed disparity between the degree of hoarseness and the objective findings in the larynx, and point the way toward a more rational treatment of early larynx disorders

DISCUSSION

Dr John A. Murtagh expressed his admiration for the film just shown which he appreciated all the more because of some experience with a highspeed Fairchild industrial motion analysis camera which he had been using in an effort to evaluate the basic physiology of the larynx in animals He confessed that his film could not compare with the one just shown This type of work should be encouraged because so much can be learned which was previously unexplained

Dr Von Leden stated that it is at first difficult to accustom oneself to viewing these pictures but that after seeing them frequently many new factors can be seen and understood

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THE MANAGEMENT OF CHRONIC LARYNGEAL STENOSIS

PAUL H HOLINGER, M D,
and
KENNETH C JOHNSTON M D*

Drs Holinger and Johnston reviewed their experiences in 163 cases of chronic laryngeal stenosis over a period of ten years Sixty-one *of these were congenital in origin, 43 were* inflammatory and 57 were traumatic Each of these types is described and illustrated by a typical case The authors have noted recently a decline in the percentage of cases due to inflammatory processes, and an increase in the number of post-traumatic lesions They point out the importance of early attention to fractures of the larynx in the prevention of subsequent stenosis from scarring and maladjusted cartilage *Tracheotomies were performed in 138 of the 163 cases* and dilatations were carried out in 123

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*By invitation

They also call attention to the value of voice therapy in the development of proper phonation and respiratory control

DISCUSSION

Dr Daniel C Baker, Jr, has found that long-continued bougienage in children is frequently disappointing In adults it is difficult because of the pain and discomfort which cannot always be avoided, even with local anesthesia or nerve block Rubber core molds as suggested by Jackson are irritating and cause considerable laryngeal reaction Mc Naught's keel is excellent for web stenoses especially the acquired type This is frequently the result of using the cautery, and he is in agreement with Dr Holinger, who advises against it. The stent graft as described by Figi, has been most useful when followed by the acrylic mold

Dr Holinger's experience with traffic injuries is most valuable, and his suggestions for their management are extremely important

Indwelling catheters for feeding in some tracheotomy cases will often delay decannulization because of reaction in the larynx due to the tube

Four cases of necrosis of the thyroid cartilage with resulting draining fistulae over a period of years were cured only after surgical removal of the diseased cartilage

Dr Holinger's presentation may well serve as a proper guide in the management of laryngeal stenosis of the chronic form

EVIDENCE OF LARYNGEAL PARTICIPATION IN EMOTIONAL EXPRESSION ITS RELATION TO HYSTERICAL APHONIA

A C FURSTENBERG, M D

Experimental electrical stimulation of various cerebral areas in the monkey have demonstrated secondary motor areas which may activate laryngeal movements These have separate and distinct pathways to the nucleus ambiguus and can carry impulses eliciting laryngeal movements even in cases of supranuclear laryngeal paralysis The secondary motor areas are in fields which, on stimulation, result in homolateral movements of the facial muscles, jaw and tongue Theoretically, therefore, it should be possible to train the larynx to function in patients with supranuclear lesions which have produced bilateral laryngeal paralysis

It was also found that some of the additional motor areas are in fields which have to do with emotional responses This has been demonstrated in a case of hysterical aphonia The patient, when aroused, may scream loudly and even speak audibly

It is also probable that the additional motor areas of the larynx, like those of other types of movements, serve as centers for automatic associated movements, as illustrated by unaware whistling, humming and talking to oneself

It is assumed on the phylogenetic basis that these experimental findings in monkeys represent a similar pattern in the human

DISCUSSION

Dr Stanton Friedberg recalled some of Dr Furstenberg s previous papers on the subject of laryngeal innervation in which the role of supranuclear lesions in the production of laryngeal paralysis were demonstrated His present contribution gives strong experimental evidence of secondary motor areas supplying pathways to the nuclei which can activate laryngeal movements While Penfield and Rasmussen demonstrated laryngeal movements through stimulation of the human cortex at surgery it remained for Dr Furstenberg to demonstrate and record them photographically and then study the postmortem specimens of cortical areas stimulated

The emotional connotations of hysterical aphonia as explained by Dr Furstenberg may not be the only factors since Jackson hinted long ago that an ephemeral adductor paralysis may be due to sudden anemia of the anterior cerebral cortex as in syncope or fainting however this has not been proven by anatomic or physiologic studies

Dr Furstenberg's suggestion that stimulation or inhibition of hypothalmic areas concerned with emotional expression may stem from certain definite regions of the brain it could supply the physiologic evidence to explain hysterical aphonia is described and illustrated by a typical case The authors have noted recently a decline in the percentage of cases due to inflammatory processes, and an increase in the number of post-traumatic lesions They point out the importance of early attention to fractures of the larynx in the prevention of subsequent stenosis from scarring and maladjusted cartilage Tracheotomies were performed in 138 of the 163 cases and dilatations were carried out in 123

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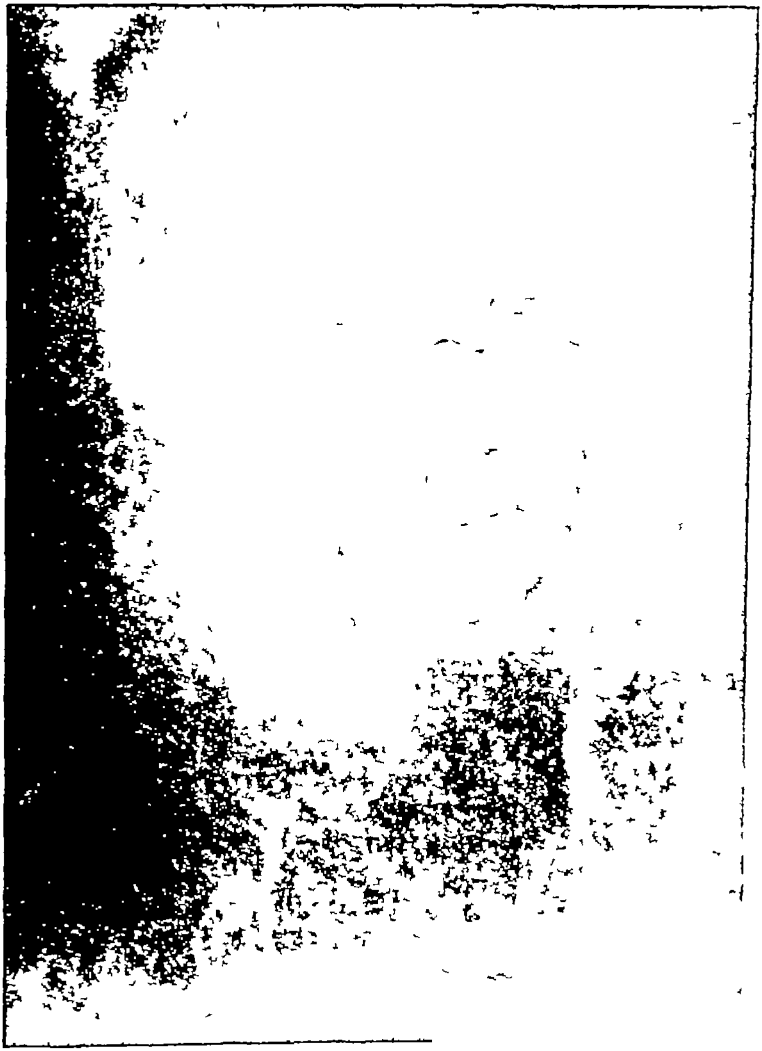

Chevalier Jackson, M D , Sc D ,
LL D , L H D , F A C S

In Memoriam

CHEVALIER JACKSON, M D , Sc D , LL D , L H D , F A C S

1865-1958

Like a Hick'ry cog,
In the old mill wheel,
He did his part,
As his turn came 'round

With these words as a postscript, Chevalier Jackson closed his autobiography He considered his life's work and responsibilities in this vein and with determination, persistence and singleness of purpose fulfilled his role in life as he saw it, in spite of hardship, adversity, discouragement and even ridicule It is gratifying to know that he lived to see his accomplishments appreciated at their full worth, and to know that many of his pioneering procedures became standard, routine techniques in both the diagnostic and therapeutic aspects of diseases of the air and food passages

Chevalier Jackson was born in Pittsburgh, Pa , on November 4, 1865 His mother and father were natives of the State French ancestry gave him his name, and a love of the French language, the culture and the country itself, throughout his life His early years in Pittsburgh, in a coal mining and farming community were rough, but habits of early rising, long hours of work and a keen interest in drawing, painting and making things with his hands were developed at this formative stage At 12 years of age he had his first experience in retrieving a foreign body—tools used in drilling for oil, lost down a 1500-foot test well The successful solution of this mechanical problem further molded his later career, the achievement of a task previously considered "impossible" continued to stimulate him throughout his life the speculum made it a practical instrument, the basic design of which has been retained in most of the present day esophagoscopes A vast experience in intubation and tracheotomy for diphtheria, and experience in the management of post-diphtheritic laryngeal stenosis acquired during the last decade of the Nineteenth Century, served as a background for subsequent work in bronchoscopy Foreign body extraction proved an absorbing challenge in the years that followed This necessitated the development of new instruments, techniques and procedures Jackson insisted on perfecting the solution of a mechanical problem of foreign body extraction by trial, first on a manikin board, then in the cadaver and finally in the anesthetized dog Constant research, self-training and discipline permitted him to achieve perfection, utilizing these progressive steps Jackson stressed the principle of education of the eye and the fingers through practical experience gained by extracting foreign bodies from the air and food passages of anesthetized dogs Physicians from every country in the world participated in the courses which he conducted in Pittsburgh, later in Philadelphia and in Paris

In 1899 Chevalier Jackson married Alice White of Pittsburgh She accepted and understood his devotion to the development of his special field of medicine She encouraged him and sheltered him from what they both considered unnecessary social obligations that might take time from study or writing, she preceded him in death by only a few months

By the turn of the Century, Jackson was receiving increasing recognition in the field of laryngology and in the new fields of bronchoscopy and esophagoscopy In 1911 he was President of the American Laryngological, Rhinological and Otological Society, and in the following year was elected Professor of Laryngology at the University of Pittsburgh, however, a change in activity was necessitated at this time by an attack of pulmonary tuberculosis Enforced rest was mandatory, but the time was far from lost Characteristically rest periods became an opportunity to write, and the first complete text on "Peroral Endoscopy and Laryngeal Surgery"

Early schooling was most difficult, not because of schoolwork, but because of the bullying by the larger, rough, miners' boys in the country school The study of medicine, as was customary at that time, was begun under a preceptor In 1884, after working for a year painting glass and china to obtain funds, Jackson entered Jefferson Medical College The medical curriculum consisted of two Winter courses of lectures and clinics from October through March At the conclusion of the first Winter course he became a salesman of medical books This took him to New England and gave him the opportunity to study his texts while waiting in doctors' offices, unfortunately the physicians usually claimed they were too busy to read books and sales were few Completing the coverage of his territory in Gloucester, Mass, Jackson shipped on a *Gloucester fishing schooner for the remainder* of the summer at $10 00 a month, plus a share in the catch Taking over as ship's cook improved his income This and his earnings from another month's work in a decorating shop painting china, enabled him to return for his second year of medical school His medical degree was conferred in 1886 when he was but 21 years of age

Specialization in a limited field was rare at that time, but interest in the field of laryngology, stimulated by the work of J Solis Cohen and the writings of Sir Morell Mackenzie led to a trip to England to visit Mackenzie's clinic Returning from Europe as a specialist at the age of 22, Jackson began his work in laryngology in Pittsburgh He demonstrated the value of tonsillectomy and adenoidectomy in children, and tried to establish a health program of throat inspection in the public school system Although this effort was unsuccessful, the experience in dealing with government agencies was of value later in pressing legislation concerning the labeling of lye as poison

His interest in endoscopy began in 1890 when he developed an esophagoscope with which he removed a dental plate from the esophagus of an adult, and a coin from a child's esophagus Adoption of Einhorn's suggestion of using a light carrier on societies throughout Europe, North, South and Central America and all parts of the United States In 1926 he was President of the American Laryngological Society and received the DeRoaldes Award in Laryngology He was a recipient of the Philadelphia Bok Award, was made a Chevalier de la Legion d' Honneur (France) and Chevalier de l'Ordre de Leopold (Belgium) in 1927 He was the recipient of the Henry Bigelow Medal awarded by the Boston Surgical Society in 1928, the Cresson Medal of the Franklin Institute in 1929, the I P Strittmatter Award in 1932, and in 1933 received the Gold Medal of the Radiological Society of North America The highest honor in American Medicine, the Distinguished Service Medal of the American Medical Association was conferred on him in 1940 The award of the American College of Chest Physicians, for meritous Services in Diseases of the Chest was given him in 1952

Jackson was the first to point out that the field of peroral endoscopy had broadened to justify considering it as an "-ology" rather than an "-oscopy", a "study of" rather than merely a "looking into" He coined the word "broncho-esophagology" to indicate this advance, and it has come into common usage Those who stumbled over its pronunciation were gently reminded of the similar term, "gastroenterology"

One of the achievements accomplished through the dogged determination so characteristic of Dr Jackson was the passage of the Federal Caustic Act by Congress in 1927 He effected this through personal appearances before numerous senators, congressmen and committees He used the many children under his care at that time as a living demonstration of the need for this legislation This law made mandatory the labeling of caustics as poisons, and required the printing of the antidote on the label Jackson obtained great personal satisfaction from this triumph The pen with which President Coolidge signed this bill was presented to him by the President

Holding five chairs of Bronchoscopy and Esophagoscopy in as many separate medical schools was a unique achieve-was prepared and published in 1914 This and an earlier text in 1907 were richly illustrated by Jackson, who stressed this form of teaching in lectures as well as texts No one who ever saw him sketch with both hands while lecturing will forget the drawings or the points they illustrated He used his line and chalk drawings, as well as oil paintings of endoscopic pathology in the texts, and they became the basic works in this new field of medicine

Foreign body work became Chevalier Jackson's greatest interest, and his skill in the management of the difficult case and his success in safely removing a foreign body after others had failed were soon recognized, however, more than anyone else, he demonstrated the value of bronchoscopy and esophagoscopy in the diagnosis and treatment of other diseases of the chest, and the safety with which these procedures could be done in infants as well as adults Peptic esophagitis, the upper and lower pinch-cock of the esophagus, bronchial adenoma, post-operative atelectasis and other phenomena he described were received with skepticism, but later were accepted as definite clinical entities In 1916 Jackson was offered the Professorship of Laryngology at Jefferson Medical College and moved to Philadelphia to accept this position Here he became recognized as the world's leading laryngologist and bronchoscopist In 1917 he was instrumental in founding the American Bronchoscopic Society and served as its first president He had been a Founder Member of the American College of Surgeons in 1913 In 1919 he was elected to fill the new chair of Bronchoscopy and Esophagoscopy created for him at the University of Pennsylvania Graduate School of Medicine He later received similar appointments at Temple University and Women's Medical College He became President of the Women's Medical College in 1935

During these years Jackson received innumerable medical honors in this country and abroad He traveled widely to give papers on bronchoscopy and allied subjects and visited all parts of the world to teach the principles and techniques of peroral endoscopy He was an honorary member of medical

Dr Jackson experienced great personal satisfaction in the establishment and subsequent development of the Chevalier Jackson Bronchoscopic Clinic of Temple University Hospital and Medical School Here, his son, Chevalier L Jackson, joined him in the clinical work and teaching program in bronchoesophagology and laryngeal surgery The quiet, friendly guidance, the teaching of technical skill and medical judgment, and finally the transfer of authority from one generation to the next, was one of the ways in which the character and wisdom of this great man were most beautifully revealed Under the son's guidance, the father's work continues

In all medical achievements the beginning can never be defined, nor the end envisioned Chevalier Jackson's influence in medicine will continue to be felt far beyond the borders of his country and the span of his life Modern medicine, as well as his individual patients, pay great homage to this man who did so much more than his part "as his turn came 'round " ment It attested to Jackson's constant drive to teach and to broaden the field of bronchoscopy In the separate clinics he developed individuals who carried on his work in strictest adherence to his principles Dr Ellen J Patterson of Pittsburgh continued his work there when he moved to Philadelphia Dr Louis Clerf continued at Jefferson Medical School, maintaining the international reputation of that world famous clinic Dr Gabriel Tucker carried on in like manner at the Graduate School as did Dr Emily Van Loon at the Women's Medical College

The great modesty, sincerity and singleness of purpose of this man, who lived through almost a century of medicine can hardly be realized He developed a specialty through keen observation, consummate skill and great perseverance He discussed its problems and their solutions with his colleagues, but his wealth of clinical experience kept him far in the lead in any consultation He gave his opinion when it was asked, but often with the disarming statemnet, "But of course, I have just one vote, you know" His kindness, gentleness, and courtesy pervaded all his actions, and these basic attitudes commanded the greatest respect from his patients and the colleagues who worked with him, yet his strict formality gave only a very few an opportunity to know him, except through medical discussions Those few who had the privilege of a visit to "The Mill" where he lived in the beautiful countryside outside of Philadelphia, saw a man keenly interested in nature and humble in his appreciation of the beauty of his surroundings He was fascinated by the mechanics of the mill wheels, the electric boat he used on the mill pond and the wood and metal tools he could use so well Even carving a roast at dinner was a task requiring a host of intruments, all laid out before him with precision and in exact order At Old Sunrise Mills he cherished the warmth of the family circle He derived great pleasure, for example, working with his granddaughter preparing the drawings for one of his last papers, illustrating the types and action of grassheads as foreign bodies in the bronchi

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Council Savoy Plaza, New York, N Y, January 10, 1959
Middle Park Plaza Hotel, St. Louis, Mo, January 12 13, 1959
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Southern Academy of Medicine, Hotel Atlanta Biltmore Atlanta Ga, January 23 24, 1959

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